Civilian Space Policy and Applications

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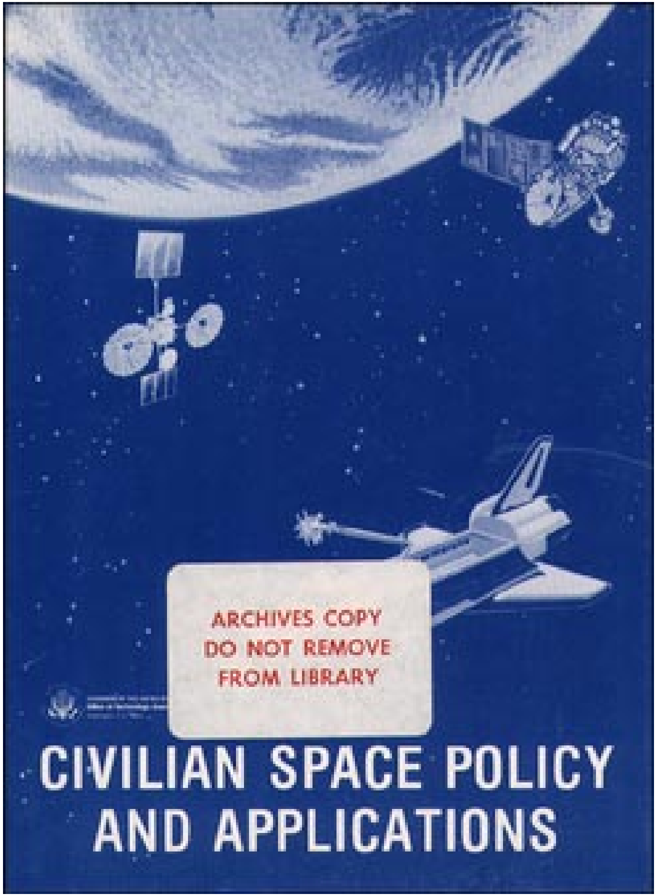

CIVILIAN SPACE POLICY
AND APPLICATIONS

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Foreword

This assessment responds to a request to the Office of Technology Assessment (OTA) from the Senate Committee on Commerce, Science, and Transportation for an evaluation of the present state and possible future directions of space applications technologies in the civilian sector. Four technologies are examined in detail: satellite communications, land remote sensing, materials processing in space, and space transportation. In addition, the assessment investigates the national policy that has guided the development of these and other applications technologies.

For the past quarter century, the United States has been the acknowledged world leader in the exploration of space and the use of technologies developed to operate in the space environment. Now, however, the United States faces increasing foreign competition in many areas of the space program, particularly in applications with commercial promise. Civilian Space Policy and Applications examines several means for addressing this competitive challenge. In particular, it investigates the options available for the future deployment of U.S. land remote-sensing systems, and explores the status of advanced satellite communications research within the National Aeronautics and Space Administration. Further, the report assesses the potential for manufacturing useful products in space and for commercializing space transportation systems.

OTA was greatly aided by the advice of the project advisory panel, as well as by participants in several specialized workshops. The contributions of contractors, who provided important analyses, and of numerous individuals and organizations that gave generously of their time and knowledge, are gratefully appreciated.

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Contents

APPENDIXES

Chapter 1

EXECUTIVE SUMMARY

Contents

Chapter 1
EXECUTIVE SUMMARY

OVERVIEW

The United States orbited its first satellite in 1958, nearly a quarter century ago. In the intervening years, the United States has made great strides in developing peaceful and practical uses of space technology. However, in spite of the dramatic successes of the space program, among which are the recent flights of the Columbia shuttle orbiter, many informed observers express considerable unease about the future of our civilian efforts in space, particularly in light of increased foreign competition and stringent fiscal restraints.

Because of these uncertainties and also because of emerging new prospects for using the space environment, this assessment was requested by the Senate Committee on Commerce, Science, and Transportation, and endorsed by the House Committee on Science and Technology. It investigates America's civilian space policy from the point of view of its effects on the primary areas of space applications technology, including space transportation. It does not address military/intelligence applications projects, activities in space science, or space exploration except insofar as

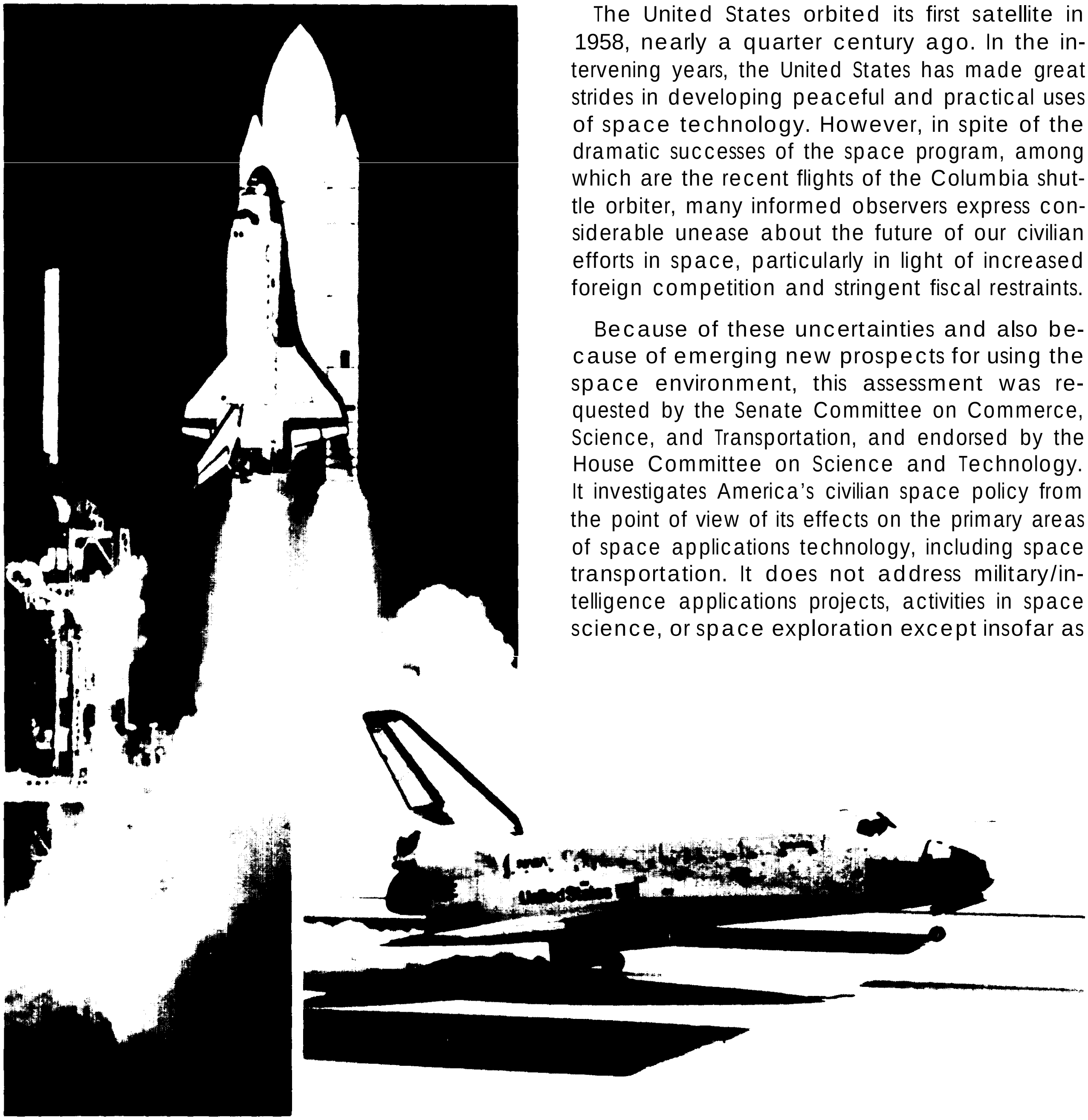


Photo credit: National Aeronautics and Space Administration

The successful launching (11-12-81) and return (11-14-81) of the second flight of space shuttle *Columbia.* The first reuse of a manned spacecraft with Astronauts Joe H. Engle and Richard H. Truly aboard these affect civilian applications. Its aim is to investigate Federal policies, public and private institutions, and the external circumstances that shape space applications today. **In keeping with this emphasis, the assessment explores the question of Federal involvement in space research and development (R&D), the issues that arise in the transition from R&D to full-fledged operational status, when and under what circumstances commercial involvement is appropriate, and how to respond to commercial competition from overseas. It also addresses questions of space policy suggested by the Nation's experience with applications of technology in space.**

SPACE POLICY

Current Status

In 1958, the basic institutions and policy principles for civilian space activities were established in the National Aeronautics and Space (NAS) Act. This supporting structure, though amended and extended by legislation and presidential directives, remains essentially unchanged to this day. During this time much has happened–not only with regard to the space program, but also with regard to the commercial, national, and international context within which the program functions.

One of the most striking changes since 1958 is that space applications are now common and pervasive parts of day-to-day life. We rely increasingly on space for vital private and public functions (commercial communications and military reconnaissance) and for useful services (land remote sensing, navigation, and weather forecasting). In the near future, we can foresee commercial possibilities for processing materials in space. All of these applications of space technology require the support of a space transportation system, including launch vehicles, spaceports, and tracking networks.

In spite of these advances, however, **there is no overall agreement about the direction or scope the civilian space program should assume in the future.** For the most part, our increasing reliance on space systems has not been appreciated by the general public, which responds most readily to spectacular manned and scientific missions.

For space applications in particular, lack of agreement on appropriate goals has made it difficult for the executive agencies to set specific timetables for developing space systems that meet user needs, to encourage private sector investment, and to initiate new and/or implement mandated programs. In addition, there is no clear and predictable policy or process to define at what rate and by what criteria the transfer of technology from Government research, development, and demonstration programs to the private sector should take place.

The lack of consensus is of concern because many desirable space activities require continued Federal support. **The Government continues to play a crucial role in at least four areas that are essential to the Nation's future in space but have little potential for immediate commercial return: contribution to advanced R&D, continuation of space science, provision of public goods and services, and regulation/coordination of national efforts, particularly with respect to international agreements.**

The failure to agree about the aims of the U.S. space program has occurred as other nations have been expanding their own programs. When the U.S. space program began, the Soviet Union was our only competitor in space. The Soviets have never challenged our leadership in space applications. Now, however, **international competition in space applications is a reality. The Europeans and the Japanese have targeted specific space technologies for development, and they will soon be providing stiff competition for services heretofore offered only by the United States.** Their increased activities threaten the loss of significant revenue opportunities for the United States as well as a potential loss of prestige and influence. Japanese and European technologies now capture a small but growing portion of the world market in satellite communications technology. Their position is likely to strengthen in time. In the near future they are also likely to be in a similar position with respect to launch services and remote-sensing systems.

Unless the United States is prepared to commit more of its public and private resources to space than it now does, it will lose its preeminence in space applications during the 1980's. Both technological and commercial leadership are at stake. The U.S. leadership position will depend not only or even primarily on spending more money, but on effectively allocating our technical, financial, and institutional resources to meet international competition. Given the likely constraints on the Federal budget, it will be important to decide in what areas the United States wishes to compete, because attempts to maintain a comprehensive program without additional capital and manpower may lead to second-best technology and systems and/or inadequate institutional support.

Although the Federal Government must continue to play an important part in space, it cannot do the job by itself. The twin factors of diminishing Federal resources for civilian space activities and the dynamic qualities of the private sector make it important that the private sector participate more actively in U.S. space efforts. A great part of the success of the European and Japanese programs results from their institutional arrangements within which private and public sectors can work well together.

Specific Issues

Amending the National Aeronautics and Space Act

The NAS Act allows for a very broad range of activities; in itself it is not a constraint on enacting or implementing U.S. programs. However, it may need to be amended to allow the National Aeronautics and Space Administration (NASA) to operate space systems after the R&D phase is complete, or explicitly to encourage commercialization of space applications technology developed under Federal sponsorship. In addition, certain provisions of the act, such as the commitment to leadership in space, and the civilian/military separation, may have to be reinterpreted in light of current needs. Possible changes or reinterpretations are raised as appropriate in the following discussion.

Civilian/Military Relationships

The separation of the military from the civilian space program has served this country well. It has allowed both programs to develop along paths that reflect their different roles and missions. The civilian program has been conducted openly and has provided spectacular technological achievements, many useful applications, and solid scientific research results; the military and national intelligence activities, while providing critical security services, have contributed significantly to our understanding of space. Cooperation and technology transfer between the two programs have involved launch vehicles, launch and recovery facilities, tracking and communications, and an array of spacecraft technologies, to the mutual benefit of both programs.

In certain cases, the sensitive and highly classified nature of military and intelligence space systems has made it difficult to transfer technology from these programs to the civilian sector. As the military program has grown in the past decade, such difficulties have become more common. The joint military and civilian roles in NASA's central program, development of the space shuttle, have raised serious questions of how to divide financial and operational responsibilities. In addition, the rise in military activities may occasion doubt in many foreign countries about the peaceful and civilian character of the civilian space program. The current climate of domestic fiscal restraint and competition with other countries argues for: 1) **more timely transfer of military technological capacity to the civilian sector; 2) assurance that past restraints on permissible civilian applications activities be reexamined; 3) appropriate assignment of lead responsibility where classified and unclassified space programs have similar technical requirements; and 4) increased joint management of programs common to both.**

Emphasis of the Program

The current institutional structure of the civilian space program is well-suited to major programs of technology development such as Apollo or shuttle. It is probably too large and too tehnologically ambitious in an environment of level or decreasing budgets for programs having few major new projects. NASA's organization would constitute an effective base for embarking on a substantial new project, but it is not well--suited to undertake broad responsibilities for operations.

Embarking on any ambitious development project involving advanced technology carries with it the inherent risk of fiscal and institutional commitment which, unless carefully planned, could overwhelm other important parts of the space program. The experience with the shuttle is illustrative of this danger. Because of insufficient allowance for unforeseen (but not unexpected) development problems, it has been significantly more expensive and difficult to bring to full operational status than originally estimated. The unintended (and unfortunate) result is that, during a period of constrained Federal budgets, important space science and space applications projects have been slighted.

Future Programs

In considering programs in space applications, one must take into account the overall context within which such an effort would take place. The future of the U.S. space program as a whole will depend on three key factors: 1) the desire to develop space technology to meet national needs, 2) the degree and kind of foreign competition, and 3) the amount of Federal and private resources available,

OTA has selected alternatives that bracket a range of possible future space programs, with emphasis on the implications for the four applications technologies addressed in the report. In the following, three possible levels of U.S. response to foreign competition are used to order options for space applications. Foreign competition was chosen as a basis for comparison because it leads to the clearest distinctions between options.

Strong Response to Competition

This response would require a strong political commitment and a consequent increase in the Federal budget for space. A strong response to competition could lead to two different space programs, depending on the nature of the competitive threat. it would follow from the evaluation that energetic development of U.S. space technology would lead to a strong competitive position for the United States in other high technology areas as well.

- ***Apollo-1ike, Government-run program.*** The structure of the U.S. civilian space program was decisively shaped in the early 1960's by the high-risk, manned Apollo program and its associated projects. As in the Apollo era, commitment to a new large centerpiece project such as a permanent manned space station, or a manned exploration of Mars could be prompted by major new civilian and military initiatives from the Soviet Union, coupled with a desire to build on the technical and institutional resources developed over the past two decades. A strong U.S. response could also include a focus on applications projects as part of an effort to emphasize certain capabilities such as communications or remote sensing in conjunction with a central program. In either case, such efforts would be Government dominated, with commercial activities probably taking a secondary place to the goal of increasing U.S. prestige.
- ***Competitive, applications-oriented program.*** A strong reaction to European, Japanese, and possible Soviet economic competition in applications systems could lead to an aggressive Federal effort to maintain U.S. technological and commercial preeminence across-the-board. It would be based on the estimation that foreign government support and subsidy for their own programs could be met only by similar support in the United States. Such a program might well be dominated by the Federal Government, but because one of its primary aims would be to develop commercial applications, strong efforts would be made to enlist private industry as a major partner.

Summary of Operational Landsat Applications in the States[a]

A. Water Resources Management
  - Surface water inventory (7)
  - Flood control mapping and damage assessment (7)
  - Snow cover mapping (3)
  - Water resources planning and management (2)
  - Irrigation demand estimation (2)
  - Determination of runoff from cropland (2)
  - Watershed or basin studies
  - Water circulation
  - Lake eutrophication survey
  - Irrigation/saline soil
  - Geothermal potential analysis
  - Ground water location
  - Offshore ice studies

B. Forestry and Rangeland Management
  - Forest inventory (6)
  - Forest productivity assessment (3)
  - Clear cut assessment (2)
  - Forest habitat assessment (2)
  - Wildlife range assessment (2)
  - Fire fuel potential
  - Fire damage assessment and recovery

C. Fish and Wildlife Management
  - Wildlife habitat inventory (9)
  - Wetlands location and analysis (3)
  - Vegetation classification
  - Snow pack mapping
  - Salt exposure

D. Land Resources Management
  - Land cover inventory (18)
  - Comprehensive planning (4)
  - Corridor analysis (2)
  - Facility siting (2)
  - Flood plain delineation
  - Solid waste management
  - Lake shore management

E. Environmental Management
  - Water quality assessment and planning (16)
  - Environmental analysis or impact assessment (4)
  - Coastal zone management (3)
  - Surface mine inventory and monitoring (2)
  - Wetlands mapping
  - Lake water quality
  - Shoreline delineation
  - Oil and gas lease sales
  - Resource inventory
  - Dredge and fill permits
  - Marsh salinization

F. Agriculture
  - Crop inventory (7)
  - Irrigated crop inventory (5)
  - Noxious weeds assessment
  - Crop yield prediction
  - Grove surveys
  - Assessment of flood damage
  - Disease monitoring

G. Geological Mapping
  - Lineament mapping (9)
  - Geological mapping (6)
  - Mineral surveys (4)
  - Powerplant siting
  - Radioactive waste storage

[a] The number in ( ) indicates the number of States for each application, where greater than 1.

SOURCE: National Governors Conference.

Moderate Response to Competition

This response would follow from an evaluation that foreign competition in space constitutes a significant, but not overriding commercial or political challenge. There are two variations:

- ***Single emphasis program*** (majority of resources devoted to a single project, e.g., the shuttle). This option describes the current situation, where NASA's other applications and science efforts have been steadily reduced as shuttle development has taken a dominant share of a constrained overall budget. Private sector involvement in applications would be strongly encouraged. Particular "targets of opportunity" would have to be selected to take best advantage of financial resources.

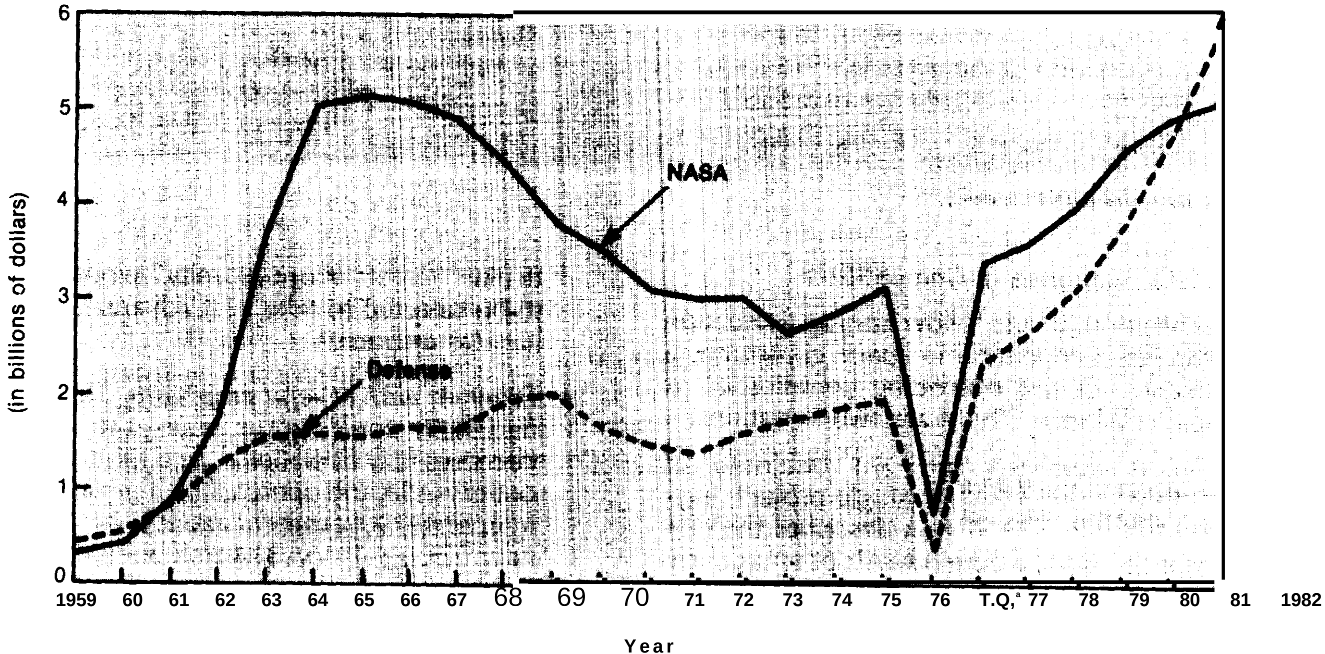
- ***Program with several emphases.*** This configuration could occur when the shuttle becomes fully operational, or if it were taken out of NASA and operated by a private firm, a separate Government agency, or the military. Though NASA's overall budget would be reduced, nontransportation applications might then have a larger and protected share of NASA'S lower budget; their portion could not be reduced as a result of increased budgeting demands from the transportation activities. Private sector participation in extended, cooperative generic R&D would be solicited to reduce costs and increase the prospects for commercialization. For similar reasons, NASA's space science programs could also be expanded.

Low Level of Response to Competition

This response would result from a view of foreign competition as either not threatening or unimportant, and a low estimate of the intrinsic value of the public benefits of space applications, coupled with severe constraints on the Federal civilian space budget.

- ***Severely constrained.*** Additional large cuts in the civilian space budget would leave very little room for new applications projects; the amount available for them would depend in part on the resources devoted to the shuttle. Major programs and perhaps entire categories of activities in science and applications would have to be eliminated and some field centers would have to be restructured or closed. Private sector efforts would be encouraged, but significant Federal funding for joint projects would not be available.
- ***Transfer of all of NASA's applications responsibilities.*** A possible response to civilian budget cuts and a weak competitive response by the United States would be to transfer any remaining Government applications programs, particularly the shuttle, to the Department of Defense (DOD) and other Government agencies. Appropriate NASA laboratories and facilities would be transferred to DOD, Interior, Commerce, and universities or private firms. NASA would retain responsibility only for basic research in space science and aeronautics, with little or no applications R&D or operational role, Such a scenario would require a radical restructuring of the civilian space program. It should be recognized that a transfer of some NASA activities to DOD may be desirable even without major budget cuts, as suggested above in the section entitled "Program with several emphases. "

Historical Budget Summary—Budget Authority



[a] T.Q. is Transitional Quarter.

SOURCE: Office of **Management and Budget,**

POLICY FOR SPACE APPLICATIONS

What are the appropriate roles of the U.S. Government in funding or otherwise encouraging civilian space applications research, development, and demonstration? Who should operate space systems once they are developed and demonstrated? Discussion of these two fundamental questions forms the basis of much of this assessment.

Federal Operation of Space Systems

At present, NASA is the civilian agency designated to conduct R&D of space systems and to operate launchers. The National Oceanic and Atmospheric Administration (NOAA) operates the weather satellites and is scheduled to assume operation of the Landsat system until the latter is transferred to private hands. Decisions on when a technically successful space system changes from R&D to operational status, and where operational responsibility lies (whether in NASA, a separate agency, a mission agency, or a private firm), have been made ad hoc. Insofar as the current procedure maintains flexibility, it has worked well; nonetheless, **the absence of guidelines for the transition from R&D to operations leads to uncertainty and inefficiency in the various programs.**

In particular, NASA's role in operating, as opposed to developing, applications systems needs to be clarified. The NAS Act itself gives NASA only limited operational responsibilities, and succeeding executive and congressional interpretations of the act make it clear that NASA is not to be primarily an operations agency, with the exception of providing launch services. Nevertheless, one approach to circumventing potential conflict between NASA and the Federal agencies which manage space systems and to easing the transition of applications systems from R&D to operational status would be to **restructure NASA's charter in the NAS Act and to allow it to operate selected Federal civilian space systems.** Such a broadening of NASA's role would require the agency to restructure itself internally so that it could gain expertise in specific mission areas.

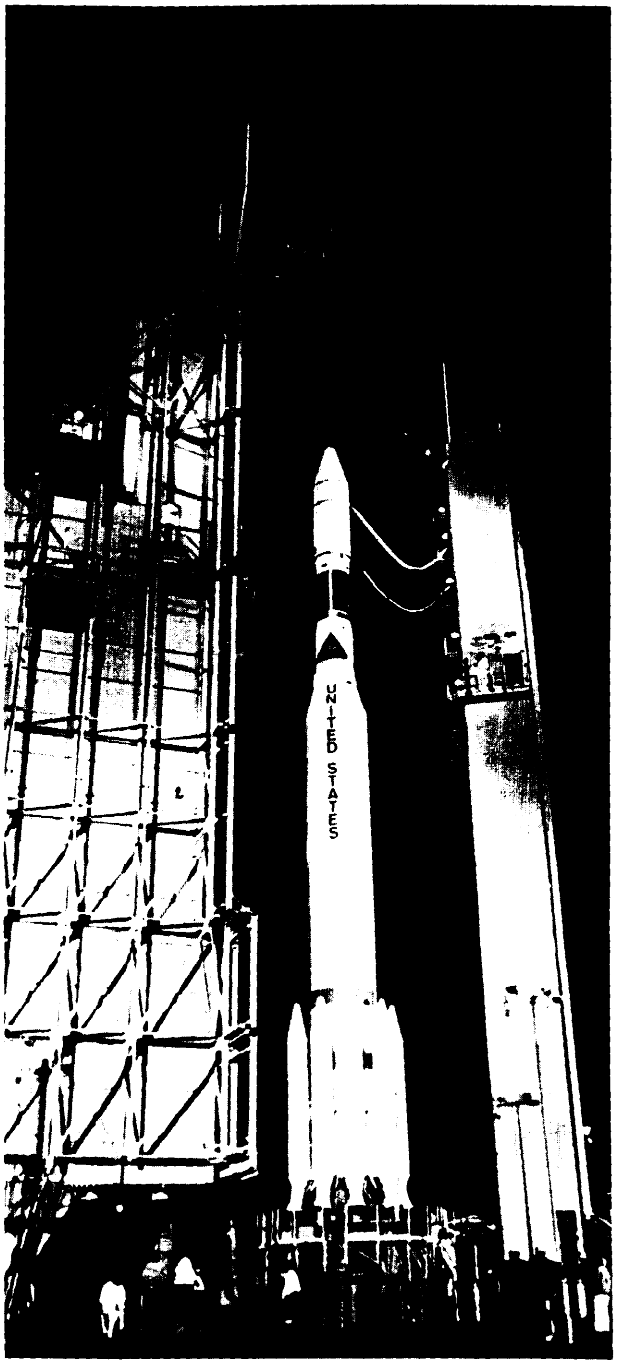


Photo credit: National Aeronautics and Space Administration

ERTS-1 satellite counting down, July 1972. The ERTS program was the first step in merging space and remote-sensing technologies into a system devoted to managing the Earth's resources more efficiently

On the other hand, insofar as the mission agencies already have the necessary knowledge and supportive institutional structures, there are good reasons to place mission-related space systems in their care. It must be noted, though, that space systems often support the activities of several mission agencies. If mission agencies are to operate space systems, the lead agency with respect to each application should be designated early in the R&D phase in order that it may be involved in designing specifications and planning for the demonstration phase, with a view to the services they are to provide to other agencies and the private sector.

Whether space systems are operated by NASA or by other Federal agencies, adequate planning for the use of space technology requires that the needs of ultimate users of the new technology be considered in the development stages. potential users must also be involved in planning and evaluating the demonstration experiments.

Commercial Ownership of Space Systems

One important way to strengthen the Nation's space program is to enlist a greater share of private resources and responsibility in space technology. To do so will require the development of innovative institutional mechanisms and incentives, examples of which are discussed later in this chapter. One way to focus attention on this aspect of the space program would be to amend the NAS Act to include commericalization as an explicit goal for appropriate space systems.

There is no single best model for commercializing space applications technologies. The particular series of steps that led to the COMSAT Corp., for example, though effective in promoting satellite communications, will not necessarily serve as a paradigm for other technologies. Commercialization of other space technologies requires that the special circumstances and different requirements of each be considered in determining whether and to what extent any system should be privately owned. At a minimum, regardless of the means considered appropriate for transfer of federally developed technology into the private sector, at a minimum interested industrial participants should be involved in planning for the demonstration phase (i.e., the phase prior to commercialization) in financing, in setting technical specifications, and in articulating the goals of potential customers.

The effectiveness of tax and other incentives *(e.g.,* patent policy and antitrust policy) for encouraging stronger industry participation in space technology R&D varies according to the technology and the industry. Though general policies such as changes in depreciation allowances or tax credits for R&D can have major effects on private investments, OTA has not evaluated the implications for space of such approaches. **The "Joint Endeavor Agreement (JEA)," recently introduced by NASA, is a promising and innovative initiative to encourage private sector interest by allowing individual treatment of industry needs in the context of NASA's overall goals.** Through JEA, NASA agrees to provide free shuttle launches and limited on-board services for private sector experiments or technology demonstration programs that meet certain criteria—such as technical merit, contribution to innovation, and acceptable business arrangements. Though originally designed to encourage private sector participation in NASA's materials processing program, **JEA, along with similar arrangements allowing for different degrees of participation, may also be useful in encouraging new advances in satellite communications and remote sensing. In addition, NASA could also encourage industrial development of space R&D by offering to launch experimental private sector devices or satellites in return for some portion of their activity being devoted to public service. Another possibility is to allow NASA to collect a royalty fee on future profits from satellites in return for a free launch.**

If the move to commercialize space applications technologies is to develop successfully, Government and industry must show an increased willingness to work together to share the risks and benefits of new technology. In particular, private firms must not expect publicly financed technologies to be transferred gratis, and Government agencies must be willing to relinquish control over their projects and to plan ahead for eventual commercialization.

Commercializing space technology raises a number of complicated regulatory issues. Domestic and international problems concerning direct broadcasting technologies, remote sensing of foreign territories without prior consent, and the development of private launch vehicles have already arisen. As the technology to support materials processing in space improves, new chemicals, alloys, and pharmaceuticals may be produced, some of which may require Government oversight to assure their content, quality, and safety. Because the technologies and the regulatory issues each raises are so different, regulation of each is best handled by agencies that specialize in each technology. In some cases, such as developing new drugs, regulatory policies (e.g., those of the Food and Drug Administration) are already in place; in others, such as private operation of launch vehicles, new policies or institutions are likely to be required.

Technologies

Of the many technologies that can be applied in space, OTA chose advanced satellite communications, land remote sensing, materials processing, and space transportation to study because: 1) these technologies raise issues that are of current interest, 2) they illustrate a range of issues faced by space applications, and 3) they have commercial potential.

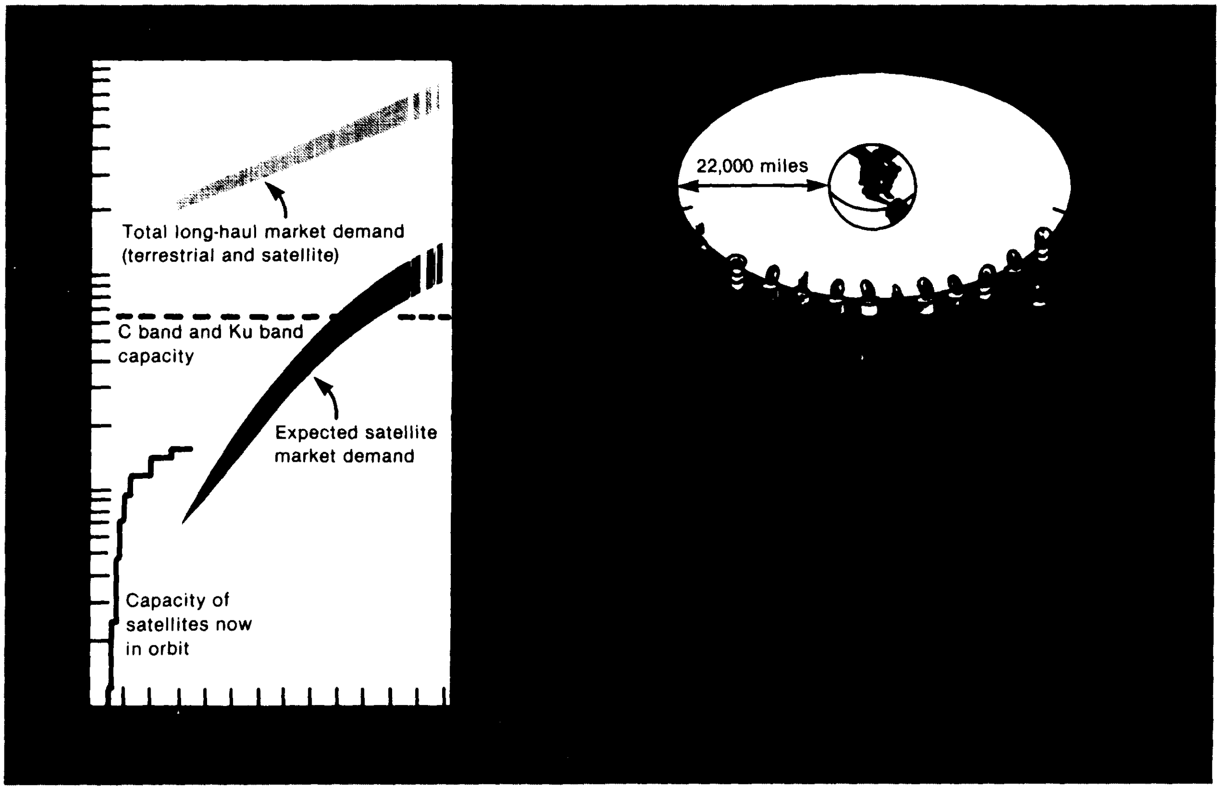
Advanced Satellite Communications

The private sector has operated communications satellite systems since 1964. Today, largely because of original research conducted by NASA and several private laboratories, the industry is flourishing. It is the most profitable area of space technology to date. In 1973, because of strong industry pressure, NASA began to phase out its advanced satellite communications research program. By 1977, however, the communications industry had decided that NASA had a role to play and urged it to begin advanced communications research again. Although NASA reinstituted a small program in 1978 ($26.7 million in 1981 and $15.9 million in 1982), it may need to be expanded. Consequently, **in order to strengthen NASA's role in supporting advances in satellite communications technology, it may be desirable for Congress to direct NASA to pursue a vigorous program in advanced satellite communications R&D.**

Projections of increasing demands for communications services, especially television distribution, indicate that technology for exploiting the Ka-band (30/20 GHz) of the radio spectrum can be developed into profitable operational systems well before 2000. Development and demonstration of this technology require at least some generic research of the sot-t not customarily done by the private sector. Already the Europeans and the Japanese are developing 30/20 GHz systems heavily subsidized by their governments. The virtual certainty that foreign systems will come online sometime in this decade has occasioned debate about whether NASA should undertake a large 30/20 technology R&D program, including flight-testing of 30/20 hardware. Proponents of a NASA program argue that the private sector alone cannot afford to develop 30/20 systems, but that if they are not developed, the United States will lose an important market and its strong lead in communications technology. An important consideration is that several companies are already doing some Ka-band work near 30/20 GHz for the military. It **appears that 30/20 development is an area in which creative new mechanisms for Government/private sector cooperation could be tried. A joint public/private demonstration project, with substantial financial participation from several corporations, might be possible and desirable. However, in order to encourage the private sector to enter into such an arrangement, appropriate incentives would have to be devised.**

On the other hand, perhaps the salient issue for commercial 30/20 systems, especially in the United States, is not whether NASA should lead the way, but when the private sector judges it appropriate to bring such systems into the market. Systems currently in use, both satellite and ground based, can still be substantially improved, and the private sector is working to do so. Until most of these improvements are made, private firms, acting alone, may not find it advantageous

The Communications Problem



SOURCE: National Aeronautics and Space Administration.

to jump to 30/20, even if firms of other nations do. However, there is no doubt that eventually the United States will need to develop 30/20. The question is when. An important consideration is that crowding of the geosynchronous orbit and the radio spectrum has led to international political problems that the private sector cannot resolve on its own. Accelerating the availability of 30/20 technology could render these problems more tractable.

The case of 30/20 demonstrates that in satellite communications, as with other space applications technology=, the United States lacks a consistent policy to assure coordination of military, civilian, and industry efforts. This absence of clear vision will again become a problem as a new configuration for communications satellites, large communication space platforms, becomes possible in the 1990's. Large communications platforms could support large multibeam antennas and the associated switching electronics needed for vastly expanded point-to-point services. The major question to be answered by a possible development and demonstration project is whether the alleviation of congestion in the geostationary orbit and reduced costs outweigh the problems of assembling them in orbit. A further important question is whether the risk of development is low enough so that the private sector will be able to develop large communications platforms on its own, or whether a NASA program is necessary or desirable, perhaps in cooperation with INTELSAT or other interested international parties.

Many of the pressing issues in satellite communications are not related directly to the use of space but concern regulation or involve questions of national sovereignty. Direct broadcast television and geostationary orbit allocation are examples of such important issues (see the recent OTA repot-t, ***Radio frequency Use and Management: Impacts From the World Administrative***

Radio ***Conference of 1979).*** Although these issues are not fully addressed **in this report, it is important to note that because the Federal Government and relevant international organizations have not decided how direct broadcast television is to be regulated, industry's investment** in this technology is laden with extra risks. Designing appropriate regulations requires considerable technical knowledge and some research. In order to aid the regulatory bodies, it may be desirable to modify NASA's legislative charter to direct the agency to support the research needs of their prospective regulatory actions.

Satellite Land Remote Sensing

The future of U.S. civilian satellite land remote sensing is in considerable doubt. The question of what to do with the U.S. system is a critical one for the future of the management and development of U.S. natural resources. Whatever is decided, the question should be resolved with dispatch. The needs of the data users make it essential that continuity of data flow be maintained and that price increases be predictable and incremental. However, at the present time, it is unclear whether the United States will have a civilian remote-sensing capability after the flight of Landsat D, and what prices will be charged for data. Landsat D is scheduled to be launched in the third quarter of fiscal year 1982 and has a mission goal of approximately 3 years.

NASA has managed the Landsat program as a quasi-operational system for several years. Under its leadership, the value of Landsat data for providing synoptic views of the Earth has been proved. The launch of Landsat D will bring this technology nearer to operational status under the management of NOAA. However, there are several general concerns about the viability of the Landsat program. First, because Landsat D will carry new and untried sensors as well as proved ones, one cannot be certain that it will provide full operational service. In addition, budget restrictions might make it difficult for NASA to complete and launch Landsat D', an identical satellite that is now in production. Finally, the determination of the French, the Japanese, and the European Space Agency to build their own satellite remote-sensing systems makes it certain that the United States will no longer have a monopoly in providing these services; the French have already begun to market their SPOT system, scheduled for operation in 1984. In addition, the Soviet Union has recently flown a new advanced land remote-sensing satellite. Although it is unclear what use they plan to make of their new capability, the Soviets could also compete with the United States in this important technology.

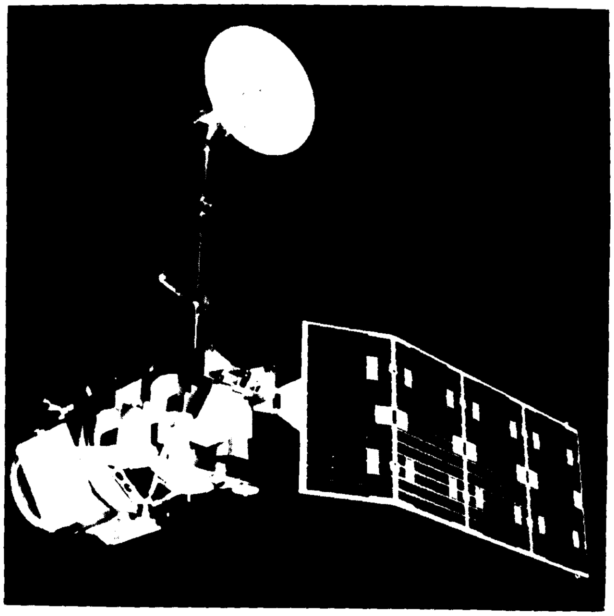


Photo credit: National Aeronautics and Space Administration

Landsat-D, an experimental satellite used primarily for monitoring and management of food and fiber resources, water resources, mineral and petroleum explorations, land cover, and land use mapping

CURRENT POLICY: PRIVATE SECTOR OWNERSHIP

Both the previous and the current administrations have **been committed in principle to commercializing a satellite remote-sensing system, but, no specific guidelines have been provided to specify the terms and speed of transition to the private sector. More than 3 years of experience in exploring the possible institutional arrangements have already demonstrated that the transition is likely to be very difficult to accomplish.** Several general proposals have been made for the means of transfer to the private sector.

- ***Designating a single entity*** (either an existing corporation, or one created by legislation) to own and operate the entire existing system (space and ground segments).
- ***Establishing a laissez-faire policy*** that would leave to the marketplace the decision to launch and operate the entire system, with the Federal Government committed to leaving the field at a specific time.
- ***Commercializing the space and terrestrial segments*** independently of one another, either through designation or laissez-faire.

Each possibility has potential benefits and drawbacks. One promising means of effecting transfer to the private sector would be to commercialize the space and the ground segments at different rates. **The ground segment already has a strong private component; the small, but important value-added industry, which processes and enhances satellite data to meet particular user needs, is certainly growing, if not yet flourishing.** The remainder of the ground segment, the receiving and processing centers, could be operated by the private sector, provided continuity of dataflow from the space segment were assured. **In the next 5 to 10 years, the market is not likely to sustain commercial operation of the entire satellite land remote-sensing system without substantial direct or indirect Government fundings.** A multilevel pricing structure, in which some users pay more than others, or an explicit subsidy to the operating entity could be used. No **matter how Government funding is provided, however, commercialization of the ground segment for land remote sensing will require a Federal commitment to the long-term, user-oriented operation of the satellite portion of the system.**

Placing the satellite land remote-sensing system in private hands creates an inherent conflict of interest for the firms that control the distribution of primary data. This might create significant problems for foreign users, particularly those less developed countries whose main economic and social potential lies in exploiting indigenous raw materials or agricultural products. Some less developed countries fear that a commercial operation may give private corporations or industrialized countries access to vital resource information before the sensed country is able to obtain it. Even if controls deemed adequate by the United States are instituted to prevent unscrupulous use of the data, other nations may still judge private control of the data to be unacceptable, and might try to promote international oversight and control in various international forums.

MULTILATERAL ALTERNATIVE TO CURRENT POLICY

The concerns of other nations might be alleviated and a much stronger market for land remote-sensing data developed if, instead of continuing a domestic system, the United States offered to share the ownership and operation of Landsat with other nations. A single multilateral management authority could assume responsibility for global operation of a land remote-sensing system; its responsibility would include establishing technical specifications, procuring and operating satellites, and receiving and preprocessing satellite data. Such an approach would spread the investment risk, as well as encourage member nations to be more aggressive in developing their own internal markets for satellite data. It could also contribute to the development of a strong market for U.S. data-processing hardware and software, and broad data-processing services. In addition, a multilateral system might make it easier to use the power of Landsat data in combination with weather satellite data to tackle some of the pressing global problems that face the world, such as the buildup of carbon dioxide, or deforestation. If the United States is to pursue the initiative of a multilateral system, it must do so soon. The French SPOT system is well along in the planning phase and the Japanese system will follow a few years after SPOT is in place. India, Brazil, and China are planning to develop their own systems in the 1990's.

However, if the system were internationalized, the United States could no longer determine its characteristics unilaterally. The United States could not guarantee that the resulting system would continue to serve U.S. needs to the same extent as the current Landsat system. To retain control, the United States would need to develop and market its next generation of Landsats in a much more aggressive manner.

CONTINUED FEDERAL OWNERSHIP

An alternative to either a privately held or an internationally owned satellite remote-sensing system is a thoroughgoing commitment to a system owned and managed by the Federal Government. Meteorological satellites, which, like Landsat, provide data of benefit to the general public, have always been owned and managed by the Government. Unlike satellite communications technology, which is already fully commercialized, and materials processing in space, which, if successful at all, seems particularly appropriate for private sector operation, satellite remote sensing could certainly be retained as a Government system on the grounds that the good it provides is primarily public. At the present time, 100 percent of the costs are borne by the Government through the budgets of NASA and the Department of the Interior, and about so percent of the data sold are "purchased" by various Government agencies. The Government, in effect, makes the market.

Materials Processing in Space

The prospects for manufacturing commercial products in space are unclear, based on data obtained to date from limited in-space and terrestrial studies. Additional fundamental science and technology research such as will be conducted in Spacelab is required before the private sector can be expected to initiate large-scale, expensive manufacturing of goods in space. However experiments that have been conducted so far do suggest that the pursuit of space processing techniques might yield unique high-value, low-volume products for the pharmaceutical, electronics, chemical, "specialty" glass, and advanced alloy industries. Much of this research will also lead to greater understanding of the effects of gravity on chemical and physical processes. At least two commercial ventures to produce commercial products or services in space are underway through joint endeavor agreements with NASA. Other firms have also begun to express interest in similar projects.

In addition to the lack of adequate knowledge, other factors that will affect the willingness of some companies to invest in space R&D are: 1) the cost of experimentation in space, 2) the leadtime needed to design experiments and schedule shuttle flights at optimal times, 3) need for multiple-flight opportunities in many cases, 4) uncertainty of return on investment, 5) industry distrust of long-term arrangements with Government, and 6) unfamiliarity with space systems and the benefits they may offer.

The United States can expect significant competition in the long term from Germany, France, Japan, and the Soviet Union, all of which are conducting a wide range of experiments in materials processing. [n the near term, according to their published plans, their efforts will concentrate on the basic science end of the R&D spectrum. Although at present it is sharply curtailed by budget reductions, the U.S. effort is directed toward commercializing this technology as well as pursuing R&D. At present it is unclear which programs will produce the greater near-term results.

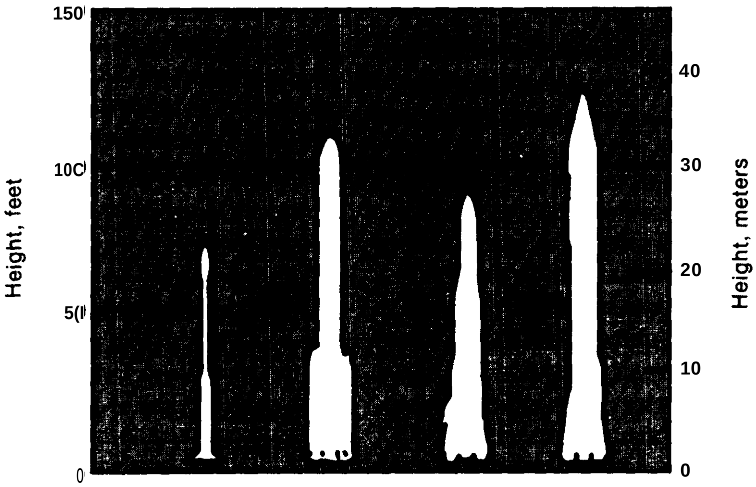
Space Transportation

Civilian space transportation, by means of both the reusable shuttle and expendable launch vehicles, is likely to remain a function of the Federal Government throughout this decade. The aerospace industry is reluctant to assume ownership of the presently operating space launching systems because: 1) the majority user is the Government, 2) the Federal Government owns and controls the existing facilities, 3) the initial investments are very high compared to expected revenues, and 4) indemnification in case of disasters (e.g., an explosion on the launch pad, or misguidance) could be very expensive.

The aerospace industry has been willing, however, to operate any and all space transportation services under contract to the Government. There has also been some limited commercialization of space transportation hardware. Upper launch stages are routinely sold directly to the user, rather than through the Government. All lower stages of expendable launch vehicles (Scout, Delta, Atlas, and Titan), however, are still purchased and launched under the control of the Federal Government.

If the Space Transportation System (the shuttle and its related components) is to be commer-

Current NASA Expendable Launch Vehicles



a) Payload values are for east launch from Eastern Test Range for Delta and Atlas Centaur
b) Scout values are for launch from wallops,
c) Atlas E/F values are for launch from Western Test Range

SOURCE: National Aeronautics and Space Administration.

cialized, the Federal Government will have to offer realistic incentives to the private sector. These might include: 1) committed purchase of an attractive number of flights, 2) provision of an accelerated schedule of investment credits, 3) low rental costs for Federal launch facilities, and 4) decision by the Government not to recoup invested costs,

NASA had planned to phase out most expendable launch vehicles in the mid 1980's as the space shuttle becomes fully operational, However, it appears that the growing future need for launch services will exceed the shuttle's availability, If demand outpaces availability, and if the United States has no expendable vehicles ready to launch commercial satellites at affordable prices, then the private sector will be forced to continue to purchase launch services from the French. NASA is now reconsidering its policy, As experience is gained with the shuttle, the launch needs for the future will be clearer than they are today, and decisions regarding the phaseout could be made in light of more realistic demand projections. It may even be appropriate to continue R&D of expendable launchers, particularly to develop a low-cost reliable launcher for boosting small payloads to geosynchronous orbit.

U.S. dominance of free world space transportation faces strong competition. The Ariane Expendable Launcher, developed by the European Space Agency, is being marketed by a private, French-incorporated company. Several U.S. companies have already changed their plans to launch on the shuttle, in favor of launching on Ariane. The Japanese now launch their own satellites by means of Delta-class launchers, which they construct under agreements with the U.S. firms that developed the technology. The Soviets and the Chinese also launch their own satellites, but with locally developed technology. The Soviets are willing to place satellites of certain other countries in orbit. Thus, although the foreign market for satellite launches is growing, foreign capability is also growing rapidly.

in addition to launch vehicles developed by the Government, at least one private U.S. company plans to build and launch its own commercial expendable launchers. This fact has caused the Federal Aviation Administration, the Federal Communications Commission, the State Department, and NASA to begin to analyze the regulatory problems that may result from private launches from the United States and other nations. At this writing, it is unclear what agency(ies) will have the responsibility for such issues as: launch authorization, aerial and maritime clearance, the development of new commercial launch sites, the need for a system of indemnification, and payload authorization. **These issues are more likely to be resolved if a lead agency is designated to coordinate launch regulations.**

International Issues

NASA has had marked success in arranging cooperative ventures in space with other countries. However, as has been noted previously, foreign competition is almost certain to increase. One result is some kinds of cooperative international ventures will become more difficult to initiate or sustain. In particular, projects having potential commercial payoff, such as future activities in materials processing that may prove of interest to chemical or pharmaceutical companies will be problematic. On the other hand, there may be more scope for joint ventures, or subcontracting, between companies from different countries, notably in selling equipment and services to the third world.

Proliferation of direct broadcast satellite systems and improvements in the resolution of civilian remote sensing data raise issues of national sovereignty and open data policy. Many countries fear that unregulated translational radio and (especially) Tv broadcasts direct to home receivers will undermine their sovereignty and their cultural values. Direct transmissions would also provide unwelcome competition for national broadcast monopolies. Issues surrounding the appropriate use of direct broadcasting systems are likely to be raised in the context of recent international proposals to regulate the free flow of information. Similarly, many countries fear that unrestricted dissemination of high-resolution remote-sensing data would threaten their sovereignty and national security. The question of requiring the prior consent of a country before selling or otherwise distributing high-resolution satellite data has been debated frequently at the United Nations and other international bodies.

Policy for Science

U.S. leadership in developing innovative technology results from the strength of its scientific, engineering, and educational institutions. innovations in space applications require that these institutions maintain their interest in the opportunities for science and engineering made possible by continued operations in space. **If the vitality of the U.S. space program is to be preserved, the United States must also be willing to commit sufficient resources and attention to basic science research and advanced engineering in all areas related to space, including space sciences.** A healthy program includes: support of educational programs in science and engineering, innovation in laboratory equipment, and basic research in science and engineering. It would maintain a strong space science effort: new missions to gather data in and from space, a corresponding set of projects to guarantee adequate analysis of these data, and a stable infrastructure of facilities and support technologies.

Charting the Policy Future

The discussion in the first section of this summary describes current problems that reach all segments of the civilian space program. A pervasive element is the lack of consistent long-term goals and clear policy initiatives, from either the executive or the legislative branches of the Government. This situation derives in part from the fact that since the Apollo decision was made in 1961, the number of major actors in civilian space activities has increased from one agency (NASA) to include six Federal agencies and numerous private firms. Not surprisingly, the many groups with direct and indirect interests in space agree neither about the overall importance of the civilian space program nor about specific applications projects. In the absence of broad consensus and a means for deciding between opposing views, the scope of individual projects is determined by the annual budget deliberations among the executive agencies, the Office of Management and Budget (OMB), and Congress. Over time, the sum of these decisions determines the overall course of the space program. However, the annual budget cycle bears little relationship to the long-term, evolutionary cycle of space systems. In addition, OMB has not chosen to view investment in space activities from a long-range perspective. Until such time as a broad consensus is formed, it is left to the President or Congress to set forth a coherent, strategic framework for civilian space policy. In the absence of such direction, the current drift will continue and worsen.

Periodic, open, high-level discussion of the space program is needed to focus attention and sharpen debate on our national objectives in space. Reviews of space policy such as those being conducted by the President's Office of Science and Technology Policy, and by Congress, including this assessment, serve part of this purpose. Nevertheless, such one-time efforts cannot substitute for a sustained forum for debate about the program. **In order to plan for the future of the space program in the context of other national needs, the United States needs a multirepresentative forum to discuss and recommend comprehensive, long-term goals. Such a forum could coordinate the interests of all the major actors in order to allow equitable and stable decisions to be made about the overall direction of the civilian space program.** Though such a body would not itself direct the course of the space program, because this responsibility lies with the President and Congress, it could focus the debate and provide timely advice.

Several different institutional options are discussed in this report. They range from establishing a new Department of R&D, of which NASA would be a part, to establishing a commission to advise the President and Congress on space. One attractive option in the executive branch would be a reconstituted and broadened National Aeronautics and Space Council, with representatives from civilian agencies, DOD, and the private sector.

Because Congress is the Government's major forum for the representation of differing views, it is there that one would expect to see the interests of different parties debated. However, space issues have not always received the coordinated attention from the committees that they probably deserve. In addition, the space activities of the Federal Government are carried out by a variety of mission agencies, most of which are not concerned primarily with space. As space technologies have developed and begun to affect so many aspects of our society, space issues have come to be dealt with in several different committees and subcommittees. If the different views are to be synthesized into a consistent space policy, coordination of responsibility is necessary. Congress would then be in position to formulate a comprehensive space policy that would set long-term goals for the U.S. space program, military and civilian.

If the congressional committees wish the issues to be raised and debated in a noncongressional environment, an option for bringing together the major interests in space would be a Presidential commission with a limited lifetime, established under concurrent resolution by Congress. To be most effective, it should also include representation from Congress. After the commission's business was completed, congressional hearings on its report could be held, followed by a new or revised charter for the space program and a clear statement of goals. This option would not remove the need for further governmental action. A temporary commission, though highly useful for initiating a new focus for the space program, cannot substitute for longer term policymaking and coordinating bodies in the executive or the legislative branches.

Chapter 2

INTRODUCTION

Contents

Chapter 2

INTRODUCTION

The space age is 25 years old. Yet in this short time period, one-third of an average citizen's lifespan, the United States has landed men on the Moon, explored portions of the two nearest planets, Mars and Venus, and flown near Jupiter and Saturn. A thriving satellite communications and data transfer industry has also been established, and a highly successful satellite weather observation system has been developed. The United States is on the threshold of an operational land remote-sensing system and will soon be experimenting with new industrial processes in space. In just a quarter of a century, this country has come to rely in a significant way on the unique vantage point and special properties of space.

The stunning success of the first flight of the space shuttle raised anew U.S. aspirations for a vital, useful space program, reflective of the recently developed technical capabilities. Yet in spite of substantial technical progress and a new capability to place men and objects in orbit, this country's civilian space policy lacks a coherent strategic framework. Though lack of clear direction affects the entire space program, public and private, it has had a particularly detrimental effect on the **applications** of space technology. In spite of the increasing dependence on space technologies, there is some uncertainty about the future direction and what questions should be asked.

Requested by the Senate Committee on Commerce, Science, and Transportation, ' and endorsed by the House Science and Technology Committee[2] this assessment attempts to lay the foundation for a broad review of national space policy, particularly as such policy may relate to civilian applications of space technology, including space transportation but not including tracking, data, and relay or navigation systems. Because the "changing nature of this country's activities in space raises a number of economic, social, legal and political questions," OTA was asked to develop "criteria and analyses to assist Congress in deciding the many complicated public policy issues that are likely to arise in charting the Nation's future in space. "

Although this report analyses the effects of policy decisions on applications of space technology, it also takes a broader view. In examining decisions made in an applications context, certain issues surfaced that affect the entire space program. The course of shuttle development, the emphasis on cost-benefit analysis, and the absence of broad consensus and consistent support for the overall space program goals have had their effects on programs outside of space applications. As far as is possible, this assessment addresses these wider policy areas and suggests policy options for making the civilian space program a more robust part of the Nation's future. It does not explore the national security space program except insofar as it affects the civilian space program.

Applications of space technology involve rather different assumptions than do scientific missions such as planetary exploration or the deployment of telescopes in space. They therefore necessitate a different policy treatment. The National Aeronautics and Space (NAS) Act of 1958 established the National Aeronautics and Space Administration (NASA) as a research and development (R&D) agency for space technology. In that role, it has served the Nation well. Yet **development** implies that a point will be reached when a new device or technical system is ready for use in an operational mode. It is at this juncture, in the transfer of developed technology to the realm of routine operation, that many of the most important issues in applications of space technology surface. Technology developed with NASA funds is technology paid for by the U.S. taxpayer. Will another agency or a private firm receive the technology? If so, how will the transfer be made? The history of the space program provides us with several examples of how that transfer can be ef-

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[1] Letter from the U.S. Senate Committee on Commerce, Science, and Transportation requesting the OTA Space Policy and Applications Assessment, September 1978.

[2] Letter from the U.S. House of Representatives Committee on Science and Technology, June 1981.

[3] Letter from the U.S. Senate Committee on Commerce, science, and Transportation, op. cit.

fected. Communications satellites were "spun off" to the private sector very early, weather satellites to the National Oceanographic and Atmospheric Administration (NOAA). Navigation satellites have remained under Department of Defense control; terminal equipment for civilian use is available commercially. Land remote-sensing satellites are at a historic juncture in their development as they pass from R&D to operational status, This assessment examines different possibilities for their future operations.

In addition to the issues raised in considering the transition from Government-supported R&D to operational status, there is a prior concern: when, where, and for how long should the Government involve itself in funding space R&D efforts? By its nature, space R&D is expensive, largely because the costs of raising people and materials beyond the atmosphere and supporting life in orbit are very high. The **risks** of R&D in space are also high, not only because traveling to space is inherently risky to humans and equipment, but also because so little is yet known about the effects of extended microgravity and high vacuum on physical and chemical processes. Even with more than two decades of experience the United States still has little more than 8 hours of experimental results on space-based processing of materials. These risks also bear an economic cost that must be taken into account when considering R&D in space. What is the proper balance between Government and private funding for R&D? What incentives are needed to encourage the private sector to assume a major role in innovation of space technology? What are the effects of emerging foreign competition on the U.S. space program?

These and other issues in the space program exist in the context of similar issues relating to Government-supported R&D in other Federal programs. Accordingly, a considerable body of analysis on this broader subject is already available. For space, however, many of the issues are too current to have been discussed in detail. Hence, a major part of OTA's task was to determine just what are the important issues for space applications. In order to identify and refine the issues that are amenable to policy treatment, OTA convened a series of workshops that drew together experts from the major space technologies OTA selected to study. They treated:

- ***Remote sensing: Government user concerns.*** Though still an R&D system, the Landsat program has provided data to users of remote-sensing data since 1972. This workshop was an effort to learn what problems some of the major users of the data had faced in the past and what concerns they have for the future as the Landsat program moves into operational status. It included Federal, State, and local users of the data, as well as representatives of two private corporations that process Landsat data, and the international banking community.
- ***Commercialization of remote land sensing.*** Several proposals have been made to transfer part or all of the current Landsat system to the private sector. This workshop convened to: 1) assess the strength of the market for remotely sensed data from space and to identify the factors that affect this market, and 2) explore appropriate models for commercializing remote sensing. Since space communications technology is already highly commercialized, OTA invited several participants who have had considerable experience with the communications satellite industry as well.
- ***Space transportation issues.*** For the present, NASA will be operating the space transportation system. What interest does private industry have in owning and/or operating a reusable shuttle-like transportation system? Is industry interested in marketing and launching expendable launch vehicles? This workshop asked these questions and, in addition, explored the nature of the incentives that the aerospace industry sees as necessary to help it do further space transportation and space construction research, development, and demonstration.
- ***Materials processing in space.*** The shuttle has raised expectations for using the special properties of space to manufacture low-mass, high-value products that cannot be made on Earth. This workshop explored the state of national and international programs in materials processing and the prospects for

manufacturing products in space. It discussed the NASA/industry Joint Endeavor Program, which brings NASA into working partnerships with other firms, and suggested other incentives that could attract industry to invest in R&D in space.

- ***International issues in commercial space systems.*** Other industrialized countries of the world also have a strong presence in space, some components of which will compete directly with U.S. systems. This workshop explored the complicated relationship between cooperation and competition in space in the free world and compared commercialization policies in the United States, Europe, and Japan. Among other topics, it discussed the private French corporations Spotimage and Arianespace, and the competitive challenge that they present to comparable U.S. systems, as well as the prospects for future multinational applications organizations like INTELSAT.

Following the development of the issues in these five workshops, OTA convened a ***Workshop on Policy Alternatives*** to consider a variety of options for addressing the major concerns identified. The workshop identified as crucial the need to develop a high-level Federal forum for reaching consensus on the direction of the space program and devoted substantial discussion to policy options addressing this need.

In addition to the workshops, several contractors contributed to this report, as well as a number of individuals conversant with the issues discussed herein. A large body of literature now exists on the space program, but we as a society are just beginning to understand the depth and breadth of its effects on our economic, social, and political fabric. Policy analysts are now able to perceive long-term effects of past decisions and can assess with more boldness the possible future effects of our efforts in space.

ORGANIZATION OF THE REPORT

Space technology, whether we are aware of it or not, is pervasive in our lives. After the presentation of the report's chief issues and findings in chapter 3 the main body of the report begins in chapter 4. Conceived out of concern over Soviet achievements in space in 1957, the NAS Act remains a basic foundation for national space policy. Chapter 4 discusses the policy history of the U.S. space program and outlines the changes that have been made since 1958 in space policy. Based on an analysis of past history, it also suggests areas for review today.

Chapter 5 begins with a discussion illustrating our dependence on space technology, followed by a summary of the current status of the U.S. space program and a short section on U.S. public attitudes and perceptions about space.

After summarizing the major features of the militarv space program and how it interacts with the civilian program, chapter 6 discusses the question of the separation between the two programs that is built into the 1958 NAS Act. It also explores the important question of transfer of technology developed for the military space programs to civilian uses, and how the pace of that transfer might be increased for the ultimate benefit of the civilian program.

Chapter 7 presents the current status of foreign space achievements and future prospects for continued cooperation and competition between the United States and other states in space science. Of major concern is the competition in space applications that foreign entities pose for U.S. efforts. This chapter also outlines some of the general foreign policy questions raised by different space policies, along with the outstanding international legal problems that could affect U.S. applications programs.

Chapter 8 summarizes the prospects for transferring the results of space R&D to the private realm for commercial exploitation, it also describes the process that American industry follows in deciding to do R&D. In a more specific way, it further develops the kinds of incentives and barriers to entering upon a program for space R&D.

Institutional effectiveness is critical to policy success. The institutional questions that have to be solved in transferring an R&D system to operational status, whether it be operated for the public good or for private profit, are complex. Because Government policy strongly conditions the framework within which private sector activities exist, chapter 9 builds on the issues concerning commercialization of R&D that are developed in chapter 7, as they relate to institutions. It also reviews the institutional frameworks that have been set up in the public good.

Whereas each of the preceding chapters raises several policy issues, chapter 10 summarizes the policy foundation of U.S. space activities. Further, it suggests new policies and integrates them with the policy framework that now exists. It analyzes a range of major policy options that could form the foundation for the U.S. future in space.

The appendixes contain material that was considered germane to the assessment, but too detailed for inclusion in the body of the report. Among these are summaries of case studies prepared for this assessment by the Bureau of Land Management and the Foreign Agricultural Services of the Department of the Interior and the National Climate Program in NOAA of the Department of Commerce. Three contributed reports on materials processing in space from the TRW Corp., McDonnell Douglas Corp., and from NASA, plus material gathered by an OTA contractor make up the case study on materials processing.

Chapter 3

ISSUES AND FINDINGS

Contents

LIST OF TABLES

Chapter 3

ISSUES AND FINDINGS

OVERVIEW

As its title indicates, the scope of this assessment has been determined by two axes: space policy as it pertains to applications and space policy in general. Although the major consideration has been to explore the issues surrounding space applications technologies, it has been important to frame that exploration by a consideration of issues germane to the entire civilian space program.

This chapter gathers the principal issues and findings of the entire assessment. Some of these are treated in greater detail elsewhere in the assessment; others, particularly those which concern the technologies themselves, are discussed in full here. The chapter has, therefore, been divided into two major sections: "General Policy Issues" and "Applications Policy Issues."

SECTION 1: GENERAL POLICY ISSUES

Introduction: The Inadequacy of Current Policy

From the beginning of the space age nearly 25 years ago, there has been general public agreement that the United States should play a major role in the utilization of space. Although there continue to be questions about appropriate funding levels and the relative priority of specific projects, the United States as a nation has been and remains committed to the development of space activities.

The National Aeronautics and Space (NAS) Act of 1958 articulated the policy principles for overall guidance of the U.S. civilian space program, but the act alone has not provided (and cannot be expected to provide) the particular goals for civilian space activities. Lacking such guidance, the space program has instead been directed by political and budgetary pressures not always relevant to a logically ordered exploration and use of space. At the same time, none of the policymaking bodies successively established in the executive branch nor any of the congressional committees have been able to ensure that a long-range plan of particular policies and programs would be pursued.

Furthermore, it may be important to recast the NAS Act to reflect the development over the past 25 years of significant U.S. capability to conduct space operations. The act was designed to develop these capabilities rather than to give guidance on how to make use of them once developed. In particular, very important services are or soon can be provided by space applications technologies, but specific policies to ensure that their potential is fully realized are not in place. The goal of this assessment, therefore, is to examine the interrelation of space policy and space applications technologies, four of which—satellite communications, land remote sensing, materials processing in space (MPS), and space transportation—are treated in detail. Weather observations and navigation are not covered except by reference. It should be noted that space transportation is not usually considered an applications technology. OTA's reason for so classifying it is that it, like the other applications, is a means to further ends, and also has a strong potential for commercialization.

Six policy principles form the core of the NAS Act. These six, which are discussed in detail later in this chapter, have provided the framework and goals in accordance with which the civilian space program has evolved to the present day. These principles may be stated as follows:

- that U.S. preeminence in space science and applications be maintained;

- that economic and social benefits be derived;
- that knowledge be increased;
- that civilian and military activities be separated (though they are to be coordinated and are not to duplicate one another unnecessarily);
- that the National Aeronautics and Space Administration (NASA), the civilian agency, be limited largely to research and development (R&D); and
- that international cooperation be fostered.

Issue 1: What Are the Key Factors of the Current Situation?

Reliance on Space

We depend increasingly on space for vital public and private services (national security and commercial communications); we rely on it for useful services (remote sensing of land, navigation, and weather reporting); we can foresee commercial possibilities for MPS in the near term. All of these space applications require an adequate space transportation system, including launch vehicles, spaceports, and tracking networks. Because of our significant reliance on space, we will certainly retain some sort of space program. However, broad agreement about the direction or scope the program should assume in the future has not been achieved. Furthermore, there is no set of procedures in place whereby a national consensus about the future program can be generated.

Need for Continued Federal Activities

Lack of basic agreement is of concern for the whole U.S. space program, not only for applications technologies. But it is of particular concern for the latter because the range of desirable civilian space applications, on account of their economic risk and high expense, cannot be undertaken by the private sector alone, in accordance with ordinary market forces. On the other hand, it is inappropriate and unnecessary for the Federal Government to undertake all of the space activities in the United States. For the foreseeable future, we will continue to be in a period of mixed public and private responsibilities. In order to ensure the success of our space ventures, a determination of the appropriate Federal role should be made and, once made, pursued consistently. In this assessment, at least four areas in which the Federal Government should continue to be involved are identified: contribution to advanced R&D, provision of public goods and services, continuation of space science, and coordination of national efforts, particularly with respect to international agreements.

International Competition

The United States no longer has a monopoly on free world space activities. The Europeans and the Japanese have targeted specific space technologies for development and are already providing stiff competition for a number of services and facilities heretofore offered only by the United States (e.g., launch facilities and communications ground stations). in particular, the French will soon be marketing an expendable launch vehicle, the Ariane, to compete with the shuttle, and they plan to begin operating, in 1984, the Systeme Probatoire d'Observation Terrestrial (SPOT) remote-sensing system to compete with the land remote-sensing satellite system (Landsat). Making good use of available U.S. technology, the Japanese are developing their own launchers, as well as communications and remote sensing satellites, particularly for ocean surveillance. The Europeans and the Japanese have also developed excellent space science programs.

The Europeans are not only technologically competitive, but have founded new semiprivate institutions, e.g., Arianespace and Spotimage, to operate and market their new systems. These institutions are subsidized by their sponsoring governments and are, therefore, able to price their services significantly lower or offer more attractive financial terms than could unsubsidized firms. In addition, their profitmaking character encourages them to seek efficiencies that a program managed by government agencies might not. Through the European Space Agency (ESA), member countries cooperate in developing advanced systems for which no one country has all the resources required (expertise as well as capital).

Need for Greater Private Sector Participation

A great part of the promise of the European and Japanese programs results from the structure of their institutions, under which private and public sectors can work well together. Their plans, however, should not necessarily cause the United States to imitate their institutional arrangements, but to discover equally effective arrangements compatible with our political and economic traditions. The twin factors of the diminution of Federal resources for civilian space activities, and the dynamism of the private sector, make it important that private corporations participate more actively in U.S. space efforts whenever commercial success is possible. if we are to develop space applications that have the most social value, signals from users must guide our efforts; it is the private sector that responds to and uses such guidance most effectively in the marketplace. Above all, we must remain flexible in determining whether one sector or the other, or some novel combination of the two, should assume the responsibility for particular activities. As responsibilities are divided, it is essential to consider both the stage of development–basic research, development, demonstration, or operations–and the kind of application—communications, remote sensing, materials processing, or transportation,

To help meet foreign commercial competition as well as to foster the more efficient use of our national resources, the United States should continue to seek further innovative relationships, like the Joint Endeavor Agreements (JEAs) sponsored by NASA, which bring public and private sectors into effective partnership in planning for and carrying out space activities. Because we have been less than effective in discovering such arrangements, many of our space applications systems have not evolved smoothly from research to operational status.

Present Government Institutions Ill-Suited to Current Conditions

By charter and by subsequent legislation, NASA is primarily responsible for the R&D of civilian space systems, not their operation. The exception to this rule is NASA's operation of space transportation systems, including launch vehicles, spaceports, and tracking systems. Responsibility for operating other federally owned civilian systems rests with the National Oceanic and Atmospheric Administration (NOAA); it operates U.S. weather satellites and is scheduled to manage the Landsat system as well.

NASA's emphasis on developing new technologies makes sense in the context of a highly visible project on which national prestige is staked. In the current political and economic context (i.e., diminishing Federal resources allocated to space, increasing competition from abroad, and growing need to involve the U.S. private sector more substantially), NASA and other Federal institutions which make extensive use of space-derived data may require reorientation, first, to ensure that a balance of diverse space activities emerges, and second, to be more responsive to user needs. Some specific suggestions for possible reorientation appear in chapter 10; chapter 9 explores the principles upon which such reorientation could be based.

Issue 2: How Are We to Manage Our Future in Space?

Future Options for the Civilian Space Program

This section considers a range of legislative approaches the Congress could take concerning applications of space technology. Although these options are derived from considering the specific technologies we have addressed in this report (i.e., satellite communications, land remote sensing, materials processing and space transportation), they generally reflect the needs of the entire spectrum of space applications. At one end of the range, Federal involvement dominates, and public goals drive the development of all space applications. At the other, Federal involvement is very low, and the pursuit of space applications is a function almost solely of private sector activity.

The U.S. space program is an investment for the Nation. Consideration of options for the U.S. space program must take into account what we **can** do, what we can **afford** to do, and what we **must** do, to meet external competition and internal demands. What we can do is determined by our technical and institutional capabilities; what we can afford to do is bounded by overall Federal resources and judged by ranking the value of space activities against other Federal programs; what we must do is driven by external challenge and domestic requirements. The relative importance to be granted these various determinants is, finally, a political decision. The shape of the resulting program can vary widely, but it is important that Congress recognize the cost of inconsistent Federal support of planned programs. The time stretching from initial concept, through research, development, and demonstration (RD&D), to final operations may include major political changes. if these changes occasion major financial perturbations, both money and talent are lost.

Our technical and institutional capabilities provide, perhaps, the least constraint. The success of Apollo proves that we can undertake and complete challenging new projects. We have a wide range of future possibilities to choose from, and we have much of the experience and expertise necessary to carry them out. The availability of Federal resources, on the other hand, is less predictable, depending, as it does, on the overall state of the economy. It is expensive to develop space technology, and for the next 3 or 4 years, at least, many Federal programs are likely to be under severe financial constraint. In addition, the relative priority of space activities in the national economy depends on an evaluation of their contribution to overall national goals. Though the need for some civilian space program is clear, its appropriate level is not. Finally, as international competition increases, serious thought must be given to planning an effective response.

Space applications exist in the context of an overall Federal commitment to the exploration and use of space for civilian and military purposes. Accordingly, the following discussion outlines the legislative choices OTA has selected for discussion and relates them to the sorts of overall programs within which they might exist. The three levels of overall commitment presented below are determined by different evaluations of foreign competition.

HIGHLY COMPETITIVE APPLICATIONS PROGRAM

As other parts of this report have stressed, the competitive challenge from other nations is strong and growing. With the exceptions of materials processing, in which competition has not yet developed because it is too new, and of navigation satellites, all space applications originally developed in the United States now face competition from other countries. For both economic and political reasons, foreign activities must be taken seriously by U.S. policymakers. Strong Federal intervention might be warranted if failure to pursue new technologies would result in significant loss of revenue or U.S. prestige, or if the threat was much greater than could be met by current Federal and private programs. A highly competitive applications program would fit most appropriately into an overall space program that seeks to achieve ambitious goals. Two different approaches bear consideration.

- ***Apollo-like program.*** Such a space program would likely arise only in response to a perceived threat from the Soviets. If they were to initiate an ambitious and highly publicized project such as a manned planetary mission, or a large, advanced orbital base, space might again become an area of superpower competition in which we tried to best Soviet efforts.

  New applications and enhanced capabilities for existing ones could result as byproducts of a singly focused space effort. The institutional structure and large budget required to complete the R&D for a single large project could lend itself, for example, to development of a new generation of communications or land remote-sensing satellites. If competition were to focus on a single dramatic project, it could spill over into a broad range of areas if the United States attempted to emphasize its across-the-board capabilities, as it did during the Apollo program. The development of the shuttle, however, argues the reverse: a single showpiece program might drain all others of much-needed funds.

  Because this program would be politically motivated, it would be aimed primarily at increasing U.S. prestige in a short period of time, and therefore would inevitably be dominated by the Government. The private sector would be seen as the source of expertise and contracting capability, but would not, at least immediately, be a prime beneficiary of U.S. programs. Encouragement of commercial activities other than those directly supportive of the major project would depend on the overall resources available: unless these resources were substantial, large crash programs could absorb funding and expertise to such a degree that other interests would receive little attention.

- ***Applications-dominated program.*** If competition from European and Japanese and, possibly, Soviet applications systems were seen as especially threatening, it might be appropriate to concentrate an aggressive Federal effort on maintaining U.S. preeminence across-the-board. This course of action would place a high value on civilian space technology as an instrument for maintaining U.S. technical capabilities and general economic strength. It would be based on the estimation that the support and subsidy of foreign governments for their own programs could be met only by similar support in the United States.

  This program would emphasize the applications segment of NASA's activities, including space transportation, and could be carried out even without a commitment to a very large single project. It would require a significant redirection away from NASA's present orientation toward spectacular missions. Except for use of the shuttle, manned programs would be reemphasized and made a part of specific applications projects, where pertinent. Space science research that contributed directly to applications efforts would receive priority; basic research that used shuttle capabilities in near Earth orbit would be favored over expensive planetary probes and long-term experiments. Like the politically motivated Apollo-type program, this highly competitive course of action would be dominated by the Government, but insofar as its aim would be leadership in commercial applications, private industry would be encouraged to become a full partner. various joint-ventures and other cooperative agreements might be encouraged. The high costs of Government subsidy in such a program could be justified as leading to eventual commercial payoff, as well as considerable public sector benefits.

MODERATELY COMPETITIVE APPLICATIONS PROGRAM

Such a response to foreign commercial competition would arise from the judgment that the United States retains significant strength in many sectors and should target "areas of opportunity" for Federal attention. Private-sector involvement in development projects and in planning for eventual takeover of potential commercial systems would be encouraged. In the near term, 30/20 GHz communications technology, land remote sensing, and space transportation are the most likely areas to receive Federal attention under this scenario. Materials processing projects would be aided, largely through use of JEAs. Federal involvement would be initiated on the grounds that the private sector cannot afford the high risks of entering a given area without help. Industry groups would be encouraged to expand their involvement by entering into joint ventures with each other and with the Government where appropriate (see ch. 8 for a full discussion of some of these possibilities). Technology transfer from military to civilian use would be increased wherever possible.

This applications program could fit the following general scenarios:

- ***Budget-constrained, with most resources devoted to a single large project (e.g., the shuttle).*** This reflects the current situation where more than 50 percent of the NASA budget is devoted to the shuttle. Although the effort to develop less expensive transportation to space will eventually benefit the entire space program, at present it has led to foreclosing or deferring many opportunities in space science and in applications. Under such conditions, if the applications program (exclusive of space transportation) is to prosper, the private sector must be involved to a much greater extent. If that involvement is not forthcoming, the U.S. competitive position will necessarily suffer. Of particular concern is the future of 30/20 GHz communications technology (see "Communications Technology," below) and land remote sensing by satellite (see "Land Remote Sensing," below).

- ***Budget-constrained– "balanced spending."*** This is not the current situation, but one that might prevail when the shuttle is fully operational and its costs are borne by the users—provided NASA's budgets stay relatively level. Under "balanced spending" conditions, an applications program (including advances in space transportation) would consume a significant portion of the budget. Space science would receive a comparable share. NASA would play a strong role in developing new communications and remote-sensing systems, in conducting experiments in materials processing, and in planning and constructing space platforms and large structures. The private sector would be solicited to participate in many of these activities.

NONCOMPETITIVE APPLICATIONS PROGRAMS

If the competition from other states is not considered especially threatening to the U.S. economy, and to our general position of leadership, and if space applications are not viewed as worth developing for the public benefits that might be derived, a greatly reduced Federal effort in space applications would be a potential policy option. Such a stance would force dependence on private investments to develop and operate space systems, but would not provide appreciable Federal funding to do so.

Although this option could apply to any of the civilian space programs considered above, it is more likely to be part of a highly constrained civilian space program:

- ***Severely constrained.*** Such a program, some 30 to 50 percent smaller than the current one, would allow little room for a civilian Federal applications effort, especially given the large percentage required for continued development of the shuttle. Major programs and perhaps entire categories of activities would be eliminated. Depending on the size of the cuts it might be necessary virtually to eliminate space science and/or defer production of parts of the space transportation system. It could not allow for a major Federal role in developing the next generation of communications satellites or remote-sensing technologies. In this situation, private attempts to develop or operate space systems would be encouraged, but significant Federal funding for joint projects would not be available. Transfer of technology developed by the military to the civilian realm could provide incentives for private involvement, especially if military spending on space were relatively unconstrained. This might allow the private sector to concentrate on modifying military-derived technologies to civilian uses and on developing areas, such as materials processing in space, where the military is not heavily involved.

DISPERSAL OF NASA'S RESPONSIBILITIES

This would result if, because of budget constraints and a desire to consolidate all Government space programs, the shuttle and other applications developments were to be transferred to the Department of Defense (DOD) and other Government agencies. Under such a scenario, advanced communications, atmospheric (weather and climate) sensing, and land and ocean remote sensing would be developed first for the military, and spun off to the private sector or civilian agencies later, if ever. Desensitized data could be made available for civilian consumption and sale to other nations through public entities or through specially licensed private corporations. However, a much more relaxed view of security would have to prevail if the data were to be as valuable as data derived from competitive international systems. Launches would be conducted by the military, with appropriate arrangements for private sector and foreign users.

NASA would retain responsibility only for basic research in space science. NASA's centers now working on applications and operations would be turned over to DOD, Interior, Commerce, or universities and private firms. Such a scenario would contravene a major premise of the NAS Act, that civilian and military space activities are to be conducted separately, and hence might require explicit legislation. It would certainly raise questions about the act's premise that "activities in space should be devoted to peaceful purposes for the benefit of all mankind."~

Toward a Coherent Federal Space Policy

partly because most civilian space technologies arise within NASA, which is primarily an agent of technology push, commercial interests and initiatives have not developed to the extent that they ordinarily do in industry. Other contributing factors include: lack of consistent congressional or executive policy direction facilitating the development of a stable market, the complexity of the technologies themselves, and the high costs and economic risks the private sector would have to bear. Aside from the general public, whose interest is periodically sparked by space spectaculars, the communities NASA serves have up to now been users rather than partners. Lacking on the one hand effective guidance from the Congress or the President, and on the other an adequate forum in which user needs may be expressed, civilian space policy is often made de facto by NASA and the Office of Management and Budget (OMB). Essentially, there are two problems. First, the United States currently lacks the appropriate means to bring the scientific, commercial, and political communities into consensus about the broad goals for civilian space activities. Second, the Federal Government has given insufficient attention to establishing arrangements whereby the private sector can be brought into effective partnership in the development and operation of civilian space systems.

Lack of foresight and, especially, lack of coordination have characterized much of the recent U.S. space effort. Increasingly, the direction and scope of our space program are determined by the annual budget deliberations among the executive agencies, OMB, and the Congress. This approach presents several problems, one of which is that annual budget cycles bear little relation to the long-term evolutionary cycle of space systems. Another is that by its nature, OMB is not well suited to view investment in space activities in long-range perspective, Finally, insofar as the civilian space program remains essentially NASA's to direct, it suffers from inattention to the concerns of users, those in the public sector, as represented by Government agencies, as well as those in the private sector. In order to focus the U.S. civilian space program and to introduce more consistency into all U.S. space activities, the President or the Congress must set forth new goals. In the absence of such direction the current drift will continue and worsen.

In order to focus attention on the country's objectives in space, periodic high-level review and discussion are needed. The Carter administration undertook several reviews of space policy under the aegis of the National Security Council which resulted in Administration Policy Directives PD-37, 42, and 54 (see ch. 10). In the Reagan administration, the Office of Science and Technology Policy (OSTP) is conducting a major policy review for a Cabinet Council chaired by the Secretary of Commerce. It is scheduled for completion sometime in 1982. Such reviews are useful for focusing attention on the needs of the space program. However, these short-term, highly focused reviews cannot substitute for sustained examination of our long-term goals in space and high-level attention to policy setting.

The many authorization and appropriations hearings on space within the Congress, as well as reports from its support agencies, keep the Congress informed on pressing space policy issues. However, because of the press of other items on the national agenda, the relatively small weight that space matters receive in most congressional districts, and the fact that space issues are dealt with in several different committees, space policy has not received sustained and broad-based attention. It would be helpful to establish a high-level, multirepresentative body to recommend goals and objectives for the overall U.S. space effort. Such a body should be able to articulate, and gain support for, the broad goals of our civilian space program, and to suggest major programs to implement these goals, though it should not be expected to achieve consensus on all the details of our future space effotts. Indeed, consensus on specific activities, e.g., the

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'National **Aeronautics and Space Act of 1958, as amended (Public Law 85-568, 85th** Cong.,H.R. **12575,** July **29, 1958, 72 Stat. 426.) sec. 102 (a).**

level of effort devoted to space science, may never be reached, for at that level, the political process of balancing competing interests (with input from the scientific establishment) properly takes precedence.

Several alternatives for this proposed body, varying in potential effectiveness and feasibility are as follows:

- ***Establish a new version of the National Aeronautics and Space Council (NASC).*** As it operated in the past, the NASC consisted of a permanent White House group, chaired by the Vice President and composed of representatives from the major Federal agencies. It was charged with recommending policy and programs directly to the president. If a future council is to be effective, its chairman would have to take a significant personal interest in space activities. A membership restricted to Federal agencies, however, would not include all of the potentially interested parties. To represent the broader perspective characteristic of the maturity of the U.S. presence in space, a reconstituted NASC should also include several members from the private sector in addition to those of the Federal agencies.
- ***Activate the Policy Review Committee (Space)*** in ***the National Security Council*** (NSC), the body charged in the Carter administration with advising and recommending on space matters. If chaired by a civilian Cabinet-level officer, it would have visibility. However, such a course of action might have the drawback of overemphasizing national security interests at the expense of the scientific, Government-user, and commercial representatives.
- ***Establish a Presidential or national commission*** composed of representatives from all the major communities interested in space. The terms of the commissioners should be long enough to outlive any particular administration. The influence of such a commission would depend on the personalities and talents of its members and the receptivity of various administrations rather than on a solid political/institutional base. Key Members of Congress should be included as members of the commission.
- Raise ***the importance of OSTP.*** Within the executive branch, civilian and military space policy is studied and formulated in OSTP and NSC. Currently, OSTP is conducting a policy review. Although this arrangement may serve as a focus for developing space policy, access to the President may not be direct enough to insure his attention to the needs of the civilian space program.
- ***Institute joint congressional hearings.*** At present, civilian space activities are reviewed by separate subcommittees of the House and Senate. For many years, both Houses had full committees responsible for space. One way to put space more prominently on the congressional agenda might be to reestablish full committees whose staff and members would have a strong interest in establishing goals and supervising their implementation. Periodic joint hearings between committees responsible for various aspects of the civilian and military space programs would help to provide coordination of national policy.

Though each option has attractive features, none appears to resolve completely the twin issues of representing all major participants fairly and adequately, and of influencing key decisionmakers. Without a commitment from the legislative and the executive branches to pursue a long-term course, none of these alternatives can be effective. However, their activities could at least define the major problems over time and ensure that regular reports are sent to the President or Congress.

Overall Prospects for Space Applications Technologies

Whereas the military and political threat of the Soviet Union sparked the initial drive toward U.S. preeminence in space, the challenge to U.S. leadership in applications programs now and for the forseeable future will come from commercial competition from our allies. The Japanese and the Europeans have heavily involved their private sectors with government programs. These government/industry partnerships have made for vigorous space programs; government contributes various kinds of subsidies and technical resources as well as a sense of national interest, the private sector contributes a whole range of commercial and technical expertise along with risk capital. Although the United States still retains its lead in technology in most space applications, foreign technical and managerial capabilities are growing rapidly.

Of the four space applications technologies here under review, U.S. success with satellite communications is in many respects exemplary. To begin with, it is flourishing. The rate of growth in this industry has been and probably will continue to be over 20 percent per year. It provides an increasingly greater range of services on which users worldwide have come to rely. The keys to its success seem to have been the early and major involvement of the private sector and a firm understanding of the potential market.

There is, however, no single model for commercializing space applications technologies. Markets for each are in different states of development; the proportion of activities aimed at public (rather than private) good varies from one technology to the next; and the maturity of the technologies themselves is not the same. Furthermore, there may be some portions of these technologies that are not at all suited for commercialization. The special needs and effects of each technology should therefore be considered in commercializing technology developed by the Government.

Issue 3: What Policy Principles Have Guided the U.S Civilian Space Program?

Before the issues specific to each of the technologies are addressed, it is useful to consider the foundation upon which the space program now rests, the 1958 NAS Act. The discussion in this section considers six of the major policy principles articulated in the act and in subsequent executive and legislative directives. Although the act contains other principles (e.g., that peaceful uses of space are to be developed, and that benefits to all mankind are to be sought), the principles selected for discussion in this assessment suffice to allow reasoned consideration of civilian space policy. Indeed, these six principles form the core of U.S. civilian space policy, and they have helped to shape the programs and institutions for implementing that policy.

The six policy principles may be stated as follows:

- that U.S. preeminence in space science and applications be maintained;
- that economic and social benefits be derived;
- that knowledge be increased;
- that civilian and military activities be separated (though they are to be coordinated and are not to duplicate one another unnecessarily);
- that NASA, the civilian agency, be limited largely to R&D; and
- that international cooperation be fostered.

Thus, the issues and findings organized by these six policy principles include those that are generic to all four technologies under review, and those that extend beyond space applications to the conduct of the entire civilian space program.

To Maintain National Preeminence

[n what sense has the United States been a leader in space applications? Is it still so today? For how long can we expect to maintain our leadership?

Especially since World War II the United States has seen itself as preeminent in science and technology and as having a special expertise in both the military and civilian applications thereof. Maintaining a technological edge has been considered crucial for several reasons. First, national security has become increasingly dependent on rapid and sustained technical advances in electronics, aerospace, and nuclear energy. Second, high technology has increasingly become a strategic sector of the economy; that is, high technology so thoroughly pervades other sectors of the economy that the United States cannot afford to be dependent on foreign countries to provide it. Other advanced nations behave similarly. Third, economic competitiveness in global markets, as well as continued domestic prosperity, stems in large part from a broad R&D base in high-technology industries. Particularly in highly developed countries such as the United States, where the costs of labor and raw materials are high, advanced technology products are a major export item. For the preceding reasons, and also because scientific and technical progress gives a general impression of vitality and strength, scientific and political decisionmakers often believe our political influence abroad to be directly dependent on national programs in the sciences and on advancements in high-technology sectors of the economy.

Attention to national preeminence has been the major formative influence on the conduct of the U.S. civilian space program. The 1958 NAS Act states as one of its aims "the preservation of the role of the United States as a leader in aeronautical and space science and technology and in the application thereof . . . "2 At its inception, the space program had to meet the perceived threat to U.S. national security from the launch of Sputnik and subsequent Soviet space initiatives. The design of our manned programs of the **1960's** and the shape of NASA's institutional structure were driven primarily by considerations of national security and political prominence, and only secondarily by regard for potential economic and scientific benefits. If the Soviets had been allowed to achieve clear superiority in any major category of space activity, they would, in the judgment of U.S. political leaders, have been likely to gain increased political support from neutral countries. As a nation, we refused to accept second place. Therefore, the United States embarked on a comprehensive and accelerated program that included the development of a variety of expendable launch vehicles, communications satellites, manned vehicles, and several orbital and planetary scientific probes. By the end of the 1960's, we succeeded in matching or bettering achievements of the Soviets in virtually every area: in addition to our celebrated victory in the race to the Moon, U.S. communications satellites were providing operational global service in the International Telecommunication Satellite Organization (I NTELSAT) system; U.S. meteorological satellites were making local weather coverage available to many parts of the world; U.S. launchers were available to other countries for scientific and applications projects; an ambitious program of unmanned planetary missions to explore Mars and the other planets was underway; and a **promising** remote-sensing technology was under development, the data from which were to be made available at low cost to all countries. As a result, the United States was able to reap the political and economic gains of unchallenged superiority in space applications.

In the following years, however, this picture began to change. Defeated in the race to man the Moon, the Soviet Union concentrated on developing a permanent manned Earth orbital laboratory, the Salyut. From 1975 to 1981, while the United States flew no manned missions, the Soviets flew 20, some of up to 6 months in duration. The Soviets conducted extensive experiments in materials processing, remote sensing, and the biological sciences, and they gained additional experience in remote-controlled rendezvous and docking, and operation of manned systems. The U. S. S.R. 'S investment in planetary exploration and space science and applications has also been extensive, in some cases more than that of the United States, but for the most part has yielded fewer results. Though less spectacular than the U.S. flights of a decade ago, the steady program of the Soviets has produced valuable experience largely unavailable in the West. Cooperative ventures with other Communist countries, as well as with India and France, have provided them significant political gains, too. Future Soviet plans are unclear, but are likely to include development of larger permanent orbital stations, an operational land remote-sensing system, high-performance boosters, and, eventually, manned planetary missions.

More important to the present situation is that Japan and several European countries have recently developed a number of advanced space technologies, many of which are comparable and in some cases superior to those of the United States and the Soviet Union. In addition, they have established a number of innovative institutional arrangements that allow significant private-sector/government cooperation. Beginning in the

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Zlbid., Sec. **102 (C)** *(5).*

early 1960's, Europe and Japan saw the importance of developing competitive space capabilities to avoid political and economic dependence on the superpowers. Though their space budgets have only been a fraction of those of the United States and the Soviet Union, their programs have achieved success by eschewing development of expensive manned capabilities, borrowing technology from the United States, and concentrating on a few key applications. Their motivations have varied, from France's highly political desire for independence and a domestic technology base to support military programs, to Japan's perception of the space market as an arena in which advanced technology is likely to yield high long-term profits. Especially significant has been the devleopment of an independent launch capability in the form of ESA'S Ariane and Japan's N-1 and N-2 vehicles.

Because of the U.S. space program's historical emphasis on very large, expensive manned programs, and because of institutional and political difficulties in transferring technology from the public to the private sector and in coordinating private sector activities, commercial competition from heavily subsidized foreign space systems may prove difficult to meet, Though the United States will retain its lead in state-of-the-art technologies and especially in manned flight, its institutional and financial capacity to support operational systems and to meet user needs is very much in question.

To Derive Economic and Social Benefits

The civilian space program has been the source of an important flow of economic and social benefits. Some of these benefits have been derived indirectly through the spinoffs from technology developed for NASA, while others have resulted from direct technology transfers to the private sector and to Government agencies. Insofar as commercialization of space applications technologies is a natural and accepted process in a capitalist society, the problems inherent in industry's attempts to commercialize technology orginally developed by or for NASA are of particular importance for this assessment.

Does the commercialization of space-based technology differ from the commercialization of Earth-based technology?

The commercialization of new technology is the last state of a complex process of innovation. Generally, this process begins with a period of basic scientific research, proceeds through a stage where practical applications are sought, and terminates in the identification of potentially marketable products. The time required for such a project, the number of participants, and the cost will all vary, depending on the nature of the research and the existing store of knowledge.

In the private sector, the decision to invest in innovation is generally motivated by desire to sustain profits. Investments in innovation, like other investments, are required to meet criteria of return on investment. Profitmaking enterprises tend to invest in projects which are designed to satisfy a recognized market or management need. Expensive, long-term, and high-risk endeavors have to be justified by a reasonable expectation of high payoff and future profit. This basic rule applies, whether the proposed innovation is in Earth- or space-based technology.

Innovation in space-based technology is inherently expensive and highly dependent on Government interest and cooperation; it involves untried technology and is often not driven by clearly defined markets. As a result, such activities cannot easily attract corporate capital. Given this generalization, it is important to review the pattern of past and current private sector investments in space technology.

The most obvious example of the successful commercialization of a space technology is the communications satellite. Early private sector interest in satellite communications was motivated by the realization that satellites provided a more efficient and less expensive alternative to the then-existing means of long-distance communication. Substantial private sector investment was later required to utilize this technology; however, the investment was made with the knowledge that the technology was well-understood and the market large and well-defined. Other space-based technologies, such as remote sensing and materials processing, do not share these advantages. Much of the present dialog about the commercialization of new space systems concerns untried technologies directed toward undefined markets. As a result, the private sector's aversion to expensive, high-risk endeavors and undefined markets has prevented and will continue to militate against major private investment in these areas.

Though reluctant to undertake the commercialization of specific space-based technologies, the private sector has been actively involved in space-related support services, providing such necessities as flight hardware, project financing, insurance, and tracking and control facilities. This limitation of private sector involvement is understandable, for these suppont services require only limited risk, and rely on preexisting and/or Government-funded technology or contracts.

To date, the major industrial participant in space activities has been the aerospace industry. This fact may be attributed to that industry's familiarity with space technology, to its close working relationship with Government, and to its willingness to take a long view of product development. Other industries have been reluctant to engage in research projects which require knowledge, personnel, and support facilities which they do not already have.

Without substantial budget support from the Government, private investment in new space technologies, such as materials processing, remote sensing, and space transportation systems, can be expected to proceed at a pace and in a manner consistent with normal investment practices in the private sector. There is some cause to believe, however, that the amount of private sector resources devoted to space may increase in the near future. This inference is largely the result of what might be termed a disaggregation of space investment opportunities. In other words, as the opportunities for relatively small investments in space technology multiply, different industries are likely to pursue individual profitmaking activities. Instead of one firm attempting to undertake a major space project, numerous firms, pursuing their own interests in particular segments of a space system, may indirectly accomplish the same result. Examples of such a situation now exist in land remote sensing and materials processing.

In land remote sensing, it is very unlikely that the private sector could finance and operate the presently structured Earth observation system. (See Issue 5.) However, it is possible that if the space and ground segments were separated, one or more private firms could profitably operate the ground segment of such a system. Similarly, in materials processing, the investment required for a single firm to identify a product, to design and launch the necessary experiments, and then to manufacture the product in space, is too great to attract industry's interest. However, recent activities in the aerospace industry indicate a willingness to design multiuser instrumentation to be used in conjunction with the shuttle for a wide va'riety of in-space research. After its development, this instrumentation would be rented to other private sector organizations for specific research projects. As the cost of in-space research is gradually spread among a number of participants, the risk to any single firm will be reduced, and the industry's investment in space should increase. (See Issue 6.)

To Increase Knowledge

The goal of increasing knowledge is more characteristic of the space sciences than of the development of applications technologies. Nonetheless, the goal of achieving a balanced and sound space policy requires that it be fostered. In addition, space science, especially studies of the near-Earth environment, plays a key role in the design and implementation of successful applications projects. An important aspect of this goal is that it mediates between maintaining national preeminence and promoting international cooperation.

NASA, the National Science Foundation (NSF), and the universities set the agenda and direction of basic space science research. The National Academy of Sciences, through its Space Science Board, also plays an important role in this process, The yearly budget process determines the level of funding for space science among the many other competitors for portions of the Federal budget.

Although this study did not assess the adequacy of the U.S. space science effort, nor the institutions and procedures used to determine its goals, it is clear that a thriving space applications technology program depends on maintaining a strong U.S. base in many key areas of science and tech nology.[3]

What problems are associated with assuming a continual growth of the knowledge base?

Conducting research in space is becoming more expensive, primarily because the easiest studies have already been done. Furthermore, justifying basic science research is difficult because direct tangible benefits from a quest for knowledge cannot be immediately shown. Thus, it is somewhat more difficult to generate public support outside of spectaculars such as the Mars Viking landing or the Voyager missions to the outer planets.

As missions have become more complex and expensive, and therefore more infrequent, it is becoming increasingly difficult for Government and universities to maintain their science teams.[4] As a result, there may soon be a narrowing of the base from which new ideas can come.

Finally, there is a tendency within NASA to focus on development and launch of new spacecraft or payloads. Anaiysis of data and interpretation of existing information or of material from past missions tend to be given lower priority and funding. In addition, the planning for data analysis prior to missions has often been inadequate. Space science has suffered from budget reductions caused by the growing costs of the shuttle program in an era of fiscal constraint. For a long time, there has been inadequate integration of space-based and ground-based science priorities, as well. Here, as in space applications, the appropriate allocation of financial resources could be assisted by an effective forum in which comprehensive and long-term national civilian space policy goals could be established.

To Keep Civilian and Military Space Activities Separate

A cornerstone of U.S. space policy has been that civilian and military programs are to be conducted separately. Up to the era of the shuttle, this separation has served the Nation well: independence of the civilian space program has reduced concerns of other nations that the United States might impose a Pax Americana in space or that space might become just another arena for military competition; good relations between NASA and DOD have reduced unnecessary duplication and promoted technology transfer; and the civilian space program has served as a high-technology analog of the Peace Corps—a point of focus for peaceful and scientific national aspirations and international cooperation.

Recent developments have led to serious concerns that the separation of the two programs may be diminished, that NASA funding and technical resources may be preempted by military uses, or even that much of the civilian program may be subsumed under the military. The shuttle in particular, which will be operated by NASA, though used by both NASA and DOD, is a compromise between the requirements of both. Because of this joint usage, there have been suggestions that DOD assume all responsibilities for space transportation.

Within certain boundaries, technology transfer from DOD to NASA has generally worked well enough in the past, but the current climate of fiscal restraint argues for a more effective, more timely transfer of military technology to the civilian sector. The United States finds itself facing considerable competition from Japan and Europe. Two different technologies illustrate the problems we face:

- ***Development of 30/20 GHz technology. In*** order to meet this competition, the United States is being pressed to begin a program to develop and demonstrate a civilian 30/20 GHz communications system. At the same time, however, military contractors are working on systems related to such a civilian system. Many believe that the technology developed for the military can be transferred to the civilian sector at a cost saving that

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[3] James A. Van Allen, "U.S. Space Science and Technology, " *Science,* Oct. 30, 1981, vol. 214, No. 4520.

[4] "Space Science Research in the United States, OTA Workshop," May 5, 1982,

would permit a commercial system to reach operational status rapidly.

- ***Development of multilinear array (MLA) technology for a civilian land remote-sensing system.*** The French are already working on MLA technology for their SPOT remote-sensing system. Although this technology is well known to military engineers, independent development of a U.S. civilian system would entail an expensive R&D program and, subsequently, an expensive demonstration project.

How can technology transfer from the military to the civilian sector be facilitated and increased?

There has been, and continues to be, a recognized need for military use of various space platforms to accomplish national defense missions. Though the civilian program is separate from DOD's program, they interact at both the management and technical levels. The 1958 NAS Act specified the establishment of a civilian agency, called for technology transfer between the civilian and military programs, and established an external coordinating mechanism, NASC, to mediate any interagency conflicts. In the intervening years, NASA's program has been subject to extensive public scrutiny, and it has developed an applications component which, because of our political philosophy and tradition, is oriented primarily toward developing systems that will eventually be operated by the private sector. The programs of DOD (and the intelligence community) have been highly classified, subject to no extensive public debate or scrutiny, and have been highly focused on mission applications. These differing objectives (and others mentioned elsewhere in this report) have led to the development of separate systems in many areas, but have not precluded common usage of certain systems.

The primary example of a common system is, of course, the shuttle. This system, the major elements of which are funded by NASA, was intended from its very beginning to satisfy the mission needs of both NASA and DOD. DOD funded the development of an interim upper stage, the shuttle launch complex at Vandenberg AFB, and extensive missions applications studies. In addition, DOD will bear the costs of producing its own shuttle-compatible payloads. Overall, the two agencies have worked well together on the shuttle program, their cooperation ensured by commitments at the highest policy levels.

At the same time, the payload programs of the two agencies (focusing on applications only) have developed along parallel, but generally separate paths. in some areas, though, DOD's technology has not been unique and, in fact, has benefited from work done by NASA and the private sector. For example, first generation military sea communications services were supplied by transponders leased from civilian maritime satellites; the FLTSATCOM system became operational later. Similarly, DOD has learned from, as well as contributed to, the technologies of geosynchronous satellite emplacement, of orbit control and station-keeping, and of satellite housekeeping (i.e., thermal control, power supplies, signal processing, etc.). In addition, the two sectors have shared information on satellite structures, altitude and attitude control, sensors, and a miscellany of such items as composition of the upper atmosphere and transmission/reflection characteristics of the Earth and its atmosphere.

There remains a significant concern about the store of military technology, largely unknown to the public, that lies behind the curtain of security classification blanketing most of DOD's activities and interests in space. It is important to recognize the nature of the barriers that exist with respect to accessibility of DOD's technology—for use either in the private sector or in the civilian public sector (by NASA or NOAA). The technology may be:

- ***Unique to a given DOD mission.*** To reveal that DOD possesses a given technology would be to reveal that a specific classified mission was being pursued.
- ***Not suitable for civilian use,*** Missions unique to DOD may require the development of systems with characteristics (and associated costs) unnecessary in the civilian sector. For example, the security and survivability criteria driving the design of many DOD systems result in a degree of redundancy and circuit hardening unneeded in civilian sat-

ellites. If, **in addition, a satellite with such characteristics were introduced into civilian use, the measures employed to ensure the survivability and security of its military twin might be compromised.**

- ***More advanced than needed for civilian applications.* In** Earth observations, for example, military intelligence requires that data of very high **resolution be collected-a standard of performance well beyond that required (or even desired) for most civilian purposes. Adoption of specific military systems or specific technology may be restricted** for several reasons: it may reveal how capable U.S. systems are, and it may reveal that a particular technology, generally considered to be well understood, achieves higher performance through special modifications. These barriers apply to a greater or lesser degree to specific Earth-sensing and communications capabilities, and they derive from concerns for national security, concerns that cannot be ignored in assessing the question of technology transfer from DOD to NASA.

However, there are cases in which the existence of a DOD technological capability (though not necessarily the latest development) has been shielded unnecessarily. In such a case, NASA has had to develop a demonstration system incorporating the same technology before it can be transferred to the public domain. Such measures are wasteful of public resources and should be given careful review in the light of current resource constraints.

To Limit NASA to R&D

With the exception of launch facilities and space transportation in general, NASA's work has been confined to R&D–largely because when the 1958 act was written, the question of Government operation of, as yet nonexistent, space applications technologies was not of great concern to the framers of the act. In addition to its many contributions to aeronautics technology, NASA has developed communications and Earth observations systems, and has studied the potential for manufacturing products in space. The experience of the past quarter century with respect to NASA's limitation to R&D has been mixed. A primary benefit of NASA's emphasis is that it has been able to make rapid technological progress because it has not had to develop expertise either in operation of service systems or in commercial development. Drawbacks include pursuit of some projects that may be impractical because they are developed with insufficient appreciation of user requirements and constraints, and inefficient transfer of technology and services to potential operators.

Prior to 1958, the National Advisory Council for Aeronautics (NACA) operated according to a general policy, set in 1946, that directed R&D to cease prior to development of specific designs of commercial aircraft equipment. This specific development was viewed as the proper role of industry. Government research was oriented toward proving a concept and generating sufficient data to permit an industrial designing process to start with a good chance of successful completion from both the technical and economic point of view. This mission is simpler for the case of aeronautical research than for space applications efforts, however, because the civil aviation market has been well defined for decades. Unfortunately, this same high degree of market articulation is not the case for all space applications technologies. The market for international communications services was rather well understood in the early 1960's. Consequently, commercialization could proceed from NASA generic R&D much as aeronautic technology did in the past. For materials processing in space, however, the market is embryonic, and simple proof of concept will not move MPS into commercialization. Thus, the precedents of how and when to shift development into the private sector fit less well for MPS.

Primarily because the NAS Act is silent on the question of who is to operate space applications (except for transportation), decisions about when a system is ready for operation, and who should be given responsibility for operating it, are made ad hoc. For satellite communications, Congress decided after much debate that responsibility for operations should reside in the private sector, but because of fears that open entry would result in a virtual communications monopoly by one firm, namely, the American Telephone and Telegraph Co. (AT&T), it created the Communications Satellite Corporation (COMSAT) in 1962. The polar orbiting TIROS weather satellite system was given to the Weather Bureau, within the Department of Commerce, to operate in 1961. When NOAA was formed in 1970, operation of the weather satellites was given to that agency. It now operates the geostationary operational environmental satellite system as well.

Land remote sensing from space, after considerable infighting among the mission agencies, was finally assigned to NOAA in 1978, principally because of its expertise in operating satellites, though it had no prior experience in the special issues surrounding land remote sensing. According to that policy decision, NOAA was also to investigate and develop mechanisms for eventually transferring Landsat to the private sector. Meanwhile, the Government committed itself to assuring continuity of the data flow from Landsat. Current policy calls for transfer of Landsat to the private sector "as soon as possible" and provides for no follow-on to the program if private operators do not assume operational responsibility. NOAA was also to operate the now-cancelled National Ocean Satellite System.

In materials processing, NASA is pursuing a vigorous basic research program. As the commercial viability of this technology becomes clearer, it seems likely that private industry, with NASA's help, will pursue specific opportunities for developing manufactured items in space. As with aeronautics or communications satellites, the Government's role in materials processing R&D will change as the technology matures.

The rationale for maintaining a separation between R&D and operations is that better, more innovative research may be done by an agency in which finding new and better ways to accomplish a task is the agency's primary concern. On the other hand, leaving an agency free from the ofien pedestrian tasks of operating a complicated technology for the public good may result in a configuration of technology that will not serve the eventual user well, either technically or economically, Also, without a closely involved client intending to assume responsibility for operations, an R&D agency may not be motivated to make appropriate tradeoffs between cost and performance; there may be unnecessary "gold plating." Furthermore, the user agency can concentrate on operations and avoid unproductive conflict between engineers and users. Users tend to be conservative: they would rather stay with a working system that they know and trust than risk their time and resources on an untried system even if it promises a vast improvement in capability. Clearly, a proper balance must be struck.

The primary issues of concern in Government-operated applications systems are when and how the transition is to be made from R&D to operational status and who has control over the course of R&D. Though different systems should be treated with flexibility as this transition is planned, the lack of clear and consistent principles for transfer introduces uncertainty and inefficiency. Perhaps the most important consideration is that potential users of a new system must be identified as soon as possible and brought into the process of planning its eventual operation. The cases of Landsat and the weather satellites have shown how difficult this transition can be to carry out. With all good will on both sides, the perceived needs of the users and the far-seeing vision of the engineers and scientists were not always compatible. One of the reasons for the user community's current dissatisfaction with certain aspects of Landsat is that it has remained an R&D system too long.

If the Government is going to be the operator of an applications system, one way to avoid interagency transition problems is to assign operational responsibility to the development agency. For space applications, NASA would assume this role, which has worked well for space transportation. In such a case, NASA would then have to develop competence in a variety of new fields in order to plan effectively for the operational phase and to carry out the plan when it is implemented. If NASA were assigned an operational role in areas other than space transportation, the transition from development to operations could be made smoother and would be more likely to lead to early returns from investment in space applications R&D. Where the period of governmental operations is likely to be of limited duration (e.g., for remote sensing), making NASA the operational agency seems appropriate.

When the private sector is to operate the applications technology once Government R&D is complete, the issues are somewhat different and involve the vital question of whether Government should be doing the R&D at all. The primary reason for the Government to sponsor R&D, as well as demonstration, in technologies intended for eventual commercial exploitation is to reduce uncertainties about the technical and economic risks associated with space applications systems. The key issue in making the transition from a Federal R&D program to a commercial operation is what additional Federal actions, if any, are needed once the technology has proved its viability, The Government has a generally weak record in understanding the marketplace, although the aeronautical program in NASA has had a long history of moving technology successfully to the private sector. As a further complication, nonaerospace industry has had little experience in working with Government on space activities.

The Federal agencies are learning how to collaborate effectively with business in the development of commercial opportunities based on Government-developed technology. Effective collaboration has been most effective in certain specific areas such as aeronautics, where the sometimes adversarial relationship between the public and private sectors has not developed. Eventually, however, the Government is likely to become more sensitive to commercial considerations in its dealings with new technology. As this kind of learning continues, Government can become a more effective partner with the Nation's investment firms and industries in maintaining U.S. economic leadership based on technological supremacy. However, there are probably inherent limitations in Government's ability to accommodate all private sector priorities.

To Foster International Cooperation

What benefits has the United States received from its cooperative programs? How is the desire for cooperation reconciled with maintaining U.S. preeminence?

The 1958 act encourages "Cooperation by the United States with other nations and groups of nations in work done pursuant to this act and the peaceful application of the results thereof."[5] Though in some ways opposed to the goal of maintaining national leadership, U.S. cooperative efforts have made useful contributions to overall political and foreign policy aims. By entering into a variety of formal and informal agreements with foreign governments (ranging from provision of scientific and technical data and participation in NASA science experiments to direct access to U.S. applications technology), the United States has encouraged potential partners to look favorably on the U.S. space effort.

In return, the United States has gained a variety of tangible and intangible benefits. At first, in the context of competition with the Soviet Union, the United States enlisted the support of allies and potential allies by offering them a stake in the new and adventurous space program. In addition, we gained access to a large number of foreign sites to provide tracking and relay stations for manned missions. Scientific data as well as general information were widely disseminated, in accordance with our basic decision—diametrically opposed to that of the Soviets—to provide the world with open coverage of U.S. successes and failures. Our civilian space program has provided a concrete demonstration of what we mean by an open society.

The United States took a leading role in establishing INTELSAT in 1964 and in arranging for broad international participation in the system. The United States profited through its initial

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[5] National Aeronautics and Space Act of 1958, Op. cit., sec.102. (c) (7).

dominance of INTELSAT and its position as the main supplier of INTELSAT hardware. Because of the position of the United States, the Soviet Union did not join INTELSAT, leaving the United States as the central figure in international satellite communications.

The United States has attempted in a number of ways to involve third-world countries in its space program. The direct-broadcast experiments conducted by NASA's applications technology satellites in 1976 enabled India and Brazil to evaluate the feasibility of transmitting educational programing to remote rural areas. The Landsat remote-sensing system was made accessible to all countries through the sale of global data at low prices, the establishment of foreign ground stations, and technical/economic assistance to less developed countries provided by the Agency for International Development. In addition to fostering goodwill, U.S. openness has helped forestall criticism directed at direct-broadcast and remote-sensing systems that operate across national boundaries.

The United States has long had a policy of selling launches—vehicles and tracking facilities—to foreign users for peaceful purposes. In one major instance of direct technology transfer, Japan has been allowed to produce Thor-Delta expendable vehicles under license. Many scientific and R&D missions have been carried out for developed and less-developed countries, in addition to cooperative ventures between NASA and outside agencies.

More recently, the rise of competitive European and Japanese capabilities, along with increasing antagonism toward the United States on the part of third-world countries, has strained our cooperative posture. European participation in the space transportation system has been extensive; the European Space Agency is building Spacelab (at its own expense), in return for free flights on the shuttle. European and Japanese payload specialists will participate in upcoming Spacelab missions. Though, overall, the Spacelab/shuttle arrangement appears to be satisfactory to both sides, differences have arisen over timing of delivery, costs, and participation in operational decisions. More generally, there are unresolved issues concerning the proper extent of cooperative ventures and of information sharing about potentially competitive commercial products, particularly in materials processing. Cancellation of the U.S. portion of the international solar polar mission (ISPM) has made the Europeans wary of entering other cooperative ventures with the United States.

In international organizations, especially the UN's Committee on Peaceful Uses of Outer Space, the U.S. position on several important legal and regulatory issues has increasingly come under attack. The United States was instrumental in drafting the major treaties dealing with outer space and in establishing the principle that broadcasting and data collection from satellites could be carried out without interference based on claims of national sovereignty. However, many third-world and Communist countries are resisting possible transmission of radio and, especially, television programing across their borders, as well as the collection and dissemination of high-resolution imagery of their territories without prior permission. Cooperation with the United States may be disrupted by disagreements over these issues, especially as Japan and Europe are rapidly becoming alternative sources of comparable services and products and may make concessions to third-world and Communist countries as a means for gaining commercial advantage over the United States.

SECTION 2: APPLICATIONS POLICY ISSUES

Introduction: Generic and Specific Technology Issues

Each of the major space applications technologies raises certain issues that are generic to all space technologies—e.g., the appropriate rate of transfer from military to civilian uses, or the appropriate role of the Government in supporting R&D. In addition, each technology also creates several issues that are specific to it alone—e.g., the resolution limit of civilian land remote sensing by satellites.

Through a series of workshops, OTA established a set of generic and specific issues that underlie this assessment. Table 1 groups these issues by technology and the policy principle under which they fit most appropriately. The generic issues were discussed in the previous section. The following section discusses the most important specific issues, technology by technology.

Table 1 .—Summary Matrix of Primary Policy Principles Across Four Major Space Application Technologies

Policy principle	Communications	Land remote sensing
Civilian/military split	1. Is the transfer of technology from the military to the civilian sector adequate? 2. Common/shared systems: a) What problems may the civilian sector face if the military can preempt civilian use? b) How should costs be shared?	1. Is the transfer of technology from the military to the civilian sector adequate? 2. What limits of resolution are appropriate to civilian systems? 3. What impact would declassifying existing military data have on prospects for transferring satellite remote sensing to the civilian sector?
International cooperation	1. How should the United States respond to foreign competition in ground and space hardware? 2. What are the impacts of Third World requirements for spectrum frequency allocation? 3. What policy focus should the United States develop toward foreign cooperation in satellite communications R&D? 4. What are the implications of U.S. application of its antitrust policies in foreign countries?	1. How will the problems of sovereignty and/or fairness be addressed? 2. What are the benefits/drawbacks of an international system for remote-sensing system? (a la INTELSAT or some other model). 3. What problems arise in our relations with other countries regarding private v. U.S. Government ownership of remote-sensing system? 4. What should U.S. policy be regarding U.S. agency use of data collected by foreign systems? 5. What is the impact of the U.S.S.R. as a competitor in remote sensing? 6. What are the effects on the foreign user of an interruption of the data flow from Landsat?
Leadership in science and technology and application thereof	1. What improvements need to be made in policy implementation? 2. How should United States respond to foreign competition? 3. What national goals or programs should the United States pursue?	1. Are we losing our leadership in land remote sensing?
NASA focus on R&D	1. What is NASA's role vis-a-vis the private sector? 2. How should program discontinuities be handled?	1. Is the policy regarding flights of opportunity adequate? 2. What steps might be taken to improve user inputs to the R&D process? 3. What continuing roles do NASA and NOAA have?
Expansion of scientific knowledge (basic science research)	1. What is NASA'S role?	1. What is NASA's role?
Development and operation of space vehicles (spacecraft)	1. What should NASA's role be regarding demonstrating publicly useful systems? 2. Do civilian agencies have a role to play in operating satellite communications systems?	1. Why hasn't the system been made operational? 2. What mechanism(s) is (are) needed to decide on the operational readiness of a technology?
Promote commercialization of civilian applications	1, How should regulatory problems (delays) be handled? 2. How should the Government regulate DBS nationality and internationally?	1. How can the market for data be aggregated and expanded? 2. How should the technology be transferred to the private sector? 3. What should policy be regarding data availability from R&D systems? 4. What incentives does industry require to commercialize remote sensing? 5. What institutional models might be appropriate? 6, How do we determine that a technology is ready for commercialization? 7. Should system continuity be assured? 8. Who should decide what sensors are required for an operational system?

Table I.—Summary Matrix of Primary Policy Principles Across Four Major Space Application Technologies (continued)

Space transportation structures	Materials processing (MPS) and manufacturing in space	Common issues
What should be DOD's role and share? 1. What problems arise from the military's right of preemption of a launch opportunity? 3. What problems occur from military influence on space transportation system design? How would this affect cost and pricing?	1! Is there adequate coordination of efforts between military and civilian sectors? 2. On what basis can a potential space-based materials lab be shared?	1. Is there adequate transfer of technology from military to civilian? 2. How should systems be shared?
1. What problems arise with the perception of shuttle as a military system? 2. How should we respond to competition from foreign transportation systems?	1. To what extent is the prospect of commercial competition detrimental to scientific cooperation?	1. What should our policies be regarding international competition? 2. What institutions may be needed to address international competition? 3. Is the United States a reliable partner for cooperative programs? 4. Is it possible or desirable for the United States to institute Government-indust~ cooperative ventures similar to those of other nations? 5. How should the United States protect technology developed by Government R&D?
1. What should the policy be regarding maintaining national facilities?	1. How should the United States respond to potential foreign competition? 2. Is Spacelab an adequate base for future MPS experiments?	1. Given that portions of U.S. policy are sound, how can policy implementation be improved? 2. Is the lack of program goals the problem with the space program or is it lack of implementation of existing policy?
1. What role can industry play as potential operator/owner of space transportation? 2. Who decides what continuing R&D is needed? 3. Should the operational system(s) pay for further R&D?	1. Who should pay for basic ground-based research? 2. Who decides what space-based research to do? Who pays?	1. What different role should Government and industry play? 2. Who should perform oversight? 3. What is NASA's role in continuing R&D after commercialization of a system?
1. What is NASA's role?		1. What is NASA's role?
1. Who will operate the space transportation system in the near term? The far term?	1. How should costs of space-based materials lab be allocated? a) How is the lab shared between Government, industry, and academia?	1. Who decides when a technology is ready for the operational mode? 2. What criteria should be used to determine the operational readiness of a technology? 3. What role should NASA have in operating proven space systems?
1. How can the market for space transportation services be aggregated? 2. How can shuttle pricing policies be made more certain? 3. What regulatory/political constraints are needed for privately run systems? 4. What incentives might be needed to encourage private investment In owning and operating space transportation components or systems?	1. What new facilities may be needed to promote space-based materials processing?	1. What steps should be taken to reduce risk to the private sector? 2. What incentives are needed to encourage private investment in space technology? 3. What should be the policy regarding operation of expendable launch vehicles? 4. What legal agreements/restraints are needed to transfer technology developed with public funding to the private sector?

SOURCE: Office of Technology Assessment.

COMMUNICATIONS SATELLITES

Issue 4: What Are the R&D Needs for Optimal Advances in Satellite Communications?

Because the satellite communications industry has already achieved the status of big business, R&D is a significant part of its competitive stance. Nonetheless, there is a point, based on industry's own view of return on investment, beyond which it is unwilling to commit funds for advanced R&D–where the risks are great, the payoffs uncertain, the technology unproved, and the time-scale of needs unclear. For this reason, the pioneers in advanced R&D are likely to be the Federal Government, industry/Government joint ventures, or, if antitrust laws permit, private consortia formed ad hoc. It is widely believed that individual firms cannot afford to finance the front-end costs of performing truly advanced development or substantial basic research,

Up to now, U.S. leadership in this field has not been threatened. But recently, Japan and several European countries have entered this field determined to compete successfully.[6] Supported by government-sponsored R&D as well as contracts awarded by INTELSAT, European and Japanese firms have developed competitive satellite subsystems and are now capable of designing, building, and operating complete telecommunications systems. In several areas, foreign development programs are more advanced than those in the United States. More concerned to maintain their competitive position with respect to one another than worried about possible antitrust violations, U.S. firms seem unwilling to coordinate an industrywide response to this potential threat to their markets.

NASA took an early lead in the development of communications satellites, and even after commercial success had been achieved, the agency continued to conduct R&D for advanced technologies. These included advanced stabilization techniques, the control of satellite position in synchronous orbit, and, in the last of the series, a demonstration of broadcast technology from the satellite to small, low-cost ground stations.

In 1973, OMB, acting on recommendations from the Office of Telecommunications Policy, greatly restricted funding for NASA's R&D **in advanced communications.** The assumption **underlying this decision was that the U.S. private** sector could conduct its own advanced R&D, making NASA's further participation mostly unnecessary. In the event, however, the private sector has, for the most part, been content to exploit proved technologies already available and to package them in even larger satellites; it has done little R&D of advanced systems. As a result, many of the new developments in satellite communication have come from the Europeans and the Japanese; in some areas they seem to have leapfrogged U.S. technology.

In this situation it is appropriate to ask what role NASA should play in responding to current needs for advanced R&D. One possibility is for NASA to proceed with plans to complete a demonstration flight of a 30/20 GHz satellite system. Other possibilities include demonstration projects for a large communications platform, and, at a much lower level of expenditure, a large deployable antenna. In addition, NASA could continue to support a number of smaller projects for 30/20 GHz subsystem work.

Increasing Use of the Geostationary Orbit

By far the most useful communications satellites are those stationed in geosynchronous orbit (GSO) in which they rotate about the Earth, in the plane of the Equator, at an angular velocity equal to that of the Earth itself. Stationed at a point above the Earth's Equator, a communications satellite in GSO can provide continuous coverage of nearly a third of the Earth's surface with a broad beam antenna.

Because many satellite systems must share relatively small numbers of orbit slots in space and frequency bands in the spectrum, there is a limit to the number of spacecraft that can be stationed in a given arc of GSO. Satellites must be sufficient-

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[6] Anthony J. Calio, **statement before the Subcommittee on Space Science and Applications of the Committee on Science and Technology, U.S. House of Representatives, 97th** Cong., **1st** sess., **July 8, 1981, p. 13.**

ly separated to avoid radio interference, the separation required for a given level of technological maturity being subject to several physical constraints. In general, satellites along the geostationary arc can use the same frequencies only if they are far enough apart so that ground stations can point at one and not receive an interfering signal from its neighbor on either side.

To guarantee noninterference, the Federal Communications Commission (FCC) and international regulatory agencies have established minimum orbital separations and have assigned satellites to specific locations called orbital slots. Each slot can accommodate one or more satellites that, between them, utilize the full range of suitable frequencies. All the slots in view of the United States are filled with existing or authorized satellites, and FCC has had to choose from several competing carriers for allocating the last few slots. When the capacity of these satellites, operating at either C or Ku band, is fully utilized (projected to occur in the last half of this decade), the growth of this industry will come to a halt–unless a solution is found and implemented.[7] Two possible solutions that will be examined here are Ka band technology and large communication platforms.

NASA’S Past and Future Roles

Through the middle 1960’s and 1970’s, NASA played a leading role in R&D for communications satellite technology. Beginning in 1973, however, NASA’s program was phased down considerably, on the assumption that the private sector would continue necessary R&D. The industry did indeed make noteworthy progress in a number of areas, but only because these areas offered: 1) a modest risk for the cost, 2) a relatively immediate market payoff, and 3) affordable development costs. As it has turned out, however, the private sector has not funded long-term, high-risk, and high-cost satellite communications research.

While the U.S. satellite communication R&D program slowed between 1973 and 1979, the Japanese and European efforts accelerated. The Japanese have already launched a direct broadcast satellite for tests and preliminary operations in the Ku band. Although the first two satellites in this program were bought from U.S. industry, all subsequent models will be made in Japan. It is also noteworthy that the Japanese have become the leading supplier of INTELSAT Earth stations and, because of very advanced technology and established production lines, are likely to take the world market lead in the sale of TV receive-only (TVRO) Earth stations designed specifically for direct-broadcast reception. Some see these efforts by the Japanese and similar activities in Europe as serious threats to the U.S. lead in satellite technology, systems, and market share.

Opportunity at 30/20 GHz

There are three frequency bands allocated for the use of civilian communications satellites: the C bands (6 GHz uplink, 4 GHz downlink), the Ku bands (14 GHz, 12 GHz), and the Ka bands (30 GHz, 20 GHz). The technology for transmission and reception in the C bands was developed first; almost all commercial satellites now operate in the C band.

Crowding at 6/4 GHz

While it is true that satellite communications systems operating in the C band (6/4 GHz) are successful and cost effective, two major problems are becoming increasingly apparent. First, the number of useful locations in GSO has been used up. With current technology, a 4° orbital separation between satellites operating in the C band is required. Not long ago, a 50 separation was required, and, as transmitting and receiving technology improves, a 3” separation may soon become standard.[8] Although it is theoretically possible to reduce the separation between satellites further, each reduction increases the costs of controlling the satellites’ susceptibility to interference. Despite the introduction of new beam-shaping technology that will further reduce interference, the point at which it becomes impractical to squeeze additional satellites operating at 6/4 GHz into desirable parking spaces in GSO is nevertheless rapidly approaching. Therefore,

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[7] General Dynamics, Convair Division, and Comsat Corporation, “Geostationary Platform Systems Concepts Definition Follow-On Study,” final review, July 28, 1981, pp. 8-38; see also, Calio, op. cit. p. 14.

[8] Calio, op. cit., p. 14.

we are indeed running out of GSO locations with good "look angles" for 6/4 systems.

The second problem is coordination with ground microwave systems operating in the 6/4 GHz bands. These ground-based systems are radio relay systems, used primarily for telex, telegraph, and voice traffic. The problems are that the satellite ground transmitters cause 6 GHz interference at the radio relay system receivers, and that the radio relay system transmitters cause 4 GHz interference at the ground receivers of the satellite system. As these ground-based systems proliferate, it has become too costly to protect colocated two-way satellite ground terminals near metropolitan areas against interference. This problem is especially acute in heavily populated areas such as Japan, Western Europe, and the Northeast United States.

FUTURE NEEDS

As demand rapidly outpaces capacity of C band satellite systems, the United States has to make some difficult decisions as to what step to take next. Should we fully develop the Ku band? Should we jump to the Ka band? Should we attempt to deploy fibre optics more rapidly? Should we buy facilities and technology for service **in the** Ku and Ka bands from the Japanese and the Europeans?

There are two main advantages of going directly to Ka: first, the enormous spectrum spread between 20 and 30 GHz allows for transmissions of much greater bandwidth and, hence, much greater versatility; and second, there are many more orbital parking slots if the Ka band is used. Projections of demand for transponders in the 1990's differ on the question of the ability of the Ku band to handle the traffic. If projections are limited to increases in voice and data traffic, technical improvements will probably allow the Ku band to suffice up to approximately 199s-2000. On the other hand, if there is a large increase in video traffic, particularly for teleconferencing, the Ku band will be exhausted by about 1992. It follows that while the Ku band represents a near-term solution to the problem of crowding in the C band—e.g., the decision of Satellite Business Systems (SBS) to operate at 14/12 GHz–projected long-term requirements can be met only by moving to the Ka band. On the other hand, there are several unresolved technical and economic questions that prevent immediate establishment of an operational Ka system.

The main advantage of developing Ku systems is that the technology is already fully tested. The disadvantage is that the Ku band will not be able to meet the needs of a greatly expanded video market. In particular, with Ku only, full action, large screen video teleconferencing will almost certainly not be possible; only the expanded capacity of 30/20 can handle the large data flow of such a high-quality system. Ku band is, however, an important interim solution; whereas C band allocations total about 700 MHz, Ku provides 1500 MHz. As a ready technology, Ku can meet a service market having three times the capacity of the already crowded C band. Ka technology on the other hand is not ready for commercial use, and experiences three to five times the transmission losses experienced at Ku.

A potential competitor to satellite systems is transmission by fibre optics. By the 1990's, fiber optics will have come into its own as a major ground-based supplier of communications needs, However, no matter how well this technology performs, or how extensive its network becomes, it will not be on-line widely enough to fulfill the requirements of the expanding markets of the 1980's. Furthermore, unlike satellite beams, fibre optics is line-switched, not area-covering; therefore, it is not so likely to be competitive for broadcast or distribution services.

COMPETITION ABROAD

The Japanese and the Europeans have already begun to develop 30/20 Ka systems. One reason that they have moved to 30/20 is that they already use the 14/1 2 Ku band for commercial radio. Therefore, if they paid exclusive attention to developing satellite systems in the Ku band, they would face the same kinds of interference problems there that plague the United States in the C band. Similarly, the United States already has INTELSAT-V and an SBS satellite and will soon have TDRSS/AW–all operating in Ku band. Five new Ku systems, to be launched in 1983-85, are under development.

More important, however, the Japanese and the Europeans have concluded that the future of satellite communications systems lies in developing systems to exploit the Ka band, though they are deploying Ku systems as well. Precisely because the Ku band represents only an interim solution, they have decided to attempt long-range domination of the satellite communications market. The Italian firm, Telespazio, for example, hopes to be in the forefront of 30/20 development, and plans to introduce a system to handle domestic telephone service and data traffic. In congressional testimony, some U.S. companies in effect agree with the foreign evaluation, albeit in hindsight, for they argue that without the continuation of a strong U.S. Government program, foreign countries will almost surely dominate the multibillion-dollar international communications satellite markets of the 1990's.[9] A strong U.S. program is, however, not synonymous with 30/20 exclusively; aggressive deployment of Ku is important also. But a renewed effort by NASA would concentrate on development and demonstration of Ka technology because the agency has already completed these tasks for Ku with the CTS experimental satellite, from 1971 to 1977. At this point, the industry has the knowledge and technology to proceed at Ku, without further need for NASA to do product improvement.

One course of action made possible by the development of 30/20 systems abroad is that U.S. firms could buy the facilities and services developed elsewhere. But to allow ourselves to fall into second place in an important area of space applications would be to ignore a basic tenet of U.S. space policy -i.e., that the United States will maintain a position of leadership. Once the United States allows itself to take a back seat in the development and deployment of this (or any) technology, it becomes ever more difficult to regain the lead. The United States cannot lightly abandon any area of technological leadership (especially in a strategic sector such as communications), given the economic importance of maintaining a favorable trade balance in high-technology products.

POTENTIAL MILITARY INTERFACE

U.S. aerospace companies are developing significant new satellite technology for the military, some of it designed for use at 30/20 GHz.[10] Those firms do not (and could not afford to) maintain separate working groups for military and civilian applications of a given technology. Rather, it is standard procedure for the same group to work on both. As important work has been done for the military at 30/20 and higher bands, the expertise exists to initiate a civilian program in short order (see ch. 6 for the broader context of this discussion).

By 1980, NASA and the Air Force had decided on joint funding of traveling wave tube development, in which the Air Force Space Division would provide 30 percent of the total funding. The Air Force, on the other hand, would handle the IMPAIT transmitter development, with NASA funding only a portion of that. For antijamming purposes, DOD is interested in a 44 GHz uplink band, but NASA is not. Thus, it seems clear that with the military interest in 30/20 (and 40), the research will continue with or without NASA.[11] Although there would be some problems with transferring the technology because of military emphases on security and survivability, such problems have been solved before and, in principle, could be in the present case.

RESPONSE OF THE PRIVATE SECTOR

In congressional testimony, private industry representatives have provided an unequivocal answer: no individual firm can finance the R&D costs of 30/20 technology.[12] On the other hand, though the industry as a whole, acting as a consortium, might be able to provide the financing, the structure of such an arrangement would have to be carefully drawn so as to conflict neither with

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[9] David McElroy, Martin Newman, and Johan Benson, statements before the Subcommittee on Space Science and Applications of the Committee on Science and Technology, U.S. House of Representatives, 97th Cong., 1st sess., July 9, 1981, p. 149.

[10] Thomas F. Rogers, Edward C. Aldredge, Jr., and Elizabeth Young, in separate statements before the Subcommittee on Space Science and Applications of the Committee on Science and Technology, U.S. House of Representatives, 97th Cong., 2d sess., Mar. 2, 1982.

[11] John H. McElroy, statement before the Subcommittee on Transportation, Aviation, and Communications and the Subcommittee on Science, Research, and Technology of the Committee on Science and Technology, U.S. House of Representatives, 96th Cong., 2d sess., May 21, 1980.

[12] Donald B. Nowakoski, statement before the Subcommittee on Space Science and Applications of the Committee on Science and Technology, U.S. House of Representatives, 97th Cong., 1st sess., July 8, 1981, pp. 56-57.

present antitrust laws nor with the competitive positions of the corporations.

This is not to say that private industry has not in the past and will not in the future engage in significant R&D. **It is, rather, to say that industrial** R&D is generally conducted in support of primary business goals. Unlike NASA's R&D, it is product- or service-oriented. Furthermore, an acceptable percentage of industrial R&D must result in profitable business applications.

Furthermore, firms in the industry see themselves as spending to the corporate limit in fulfilling needs for short-term R&D. There are not enough funds to be applied to a long-term program like civilian 30/20. NASA estimates, and industry concurs, that the agency's flight program to test 30/20 technology will cost $250 million to $400 million over 3 to 5 years. A commercial R&D program in satellite communications hardware (which a carrier conducts in a lab) is, by contrast, on the order of $10 million per year.

SOME CONCERNS

One reason for concern is that the costs of flight testing 30/20 technology are estimated on the assumption that NASA would do the tests. It is often the case (and industry makes it frequently in other contexts) that industry can do certain kinds of tasks more economically than government can. Presumably, therefore, if one of the large aerospace companies conducted flight tests of 30/20 technology for civilian use, the costs would be substantially lower. Whether industry would argue that they still could not undertake the necessary R&D, even if the Government furnished launch, data acquisition, and tracking services free, is an open question. The complicating factor, however, is that no appropriate spacecraft bus exists. It is not certain that a Ku-band bus will suit Ka-band technology. if a new spacecraft is required, it will cost over **$100** million, excluding the costs of the new communications hardware to be tested. Nevertheless, if, for example, a consortium of the major satellite firms, builders and carriers, received contributions of $10 **million dollars** per year from each, over a 5-year period, a demonstration project could be privately funded.

A second reason for skepticism is that the risks seem somewhat overestimated. The technology has already been bench-tested; the launch systems are not problematic. Thus, besides the complex but manageable business of developing a suitable spacecraft, there remains only the task of mating proved technology and reliable launch facilities. Additionally, market studies of the commercial potential of Ka-band technology have been made and have been uniformly encouraging. ' [3]In short, the technical risks do not seem great, while the prospects of return are high.

A final area of concern, one which verges on questions of policy, is that insufficient consideration seems to have been given to the possibility of establishing a joint management structure for development of 30/20 technology. The Government might be a guarantor or a partner in such an arrangement, One potentially attractive Government-industry relationship for 30/20 technology, as well as for the large communications platform, might be a variation on the JEA currently instituted to promote materials processing in space. In such an agreement, the Government could offer to bear the cost of launching a communications satellite in return for a guarantee of a specified amount of public service communications from the satellite. If successful, both parties would benefit, If not, the losses would be shared.

Large Communications Platforms

TECHNICAL CHARACTERISTICS

As ***one*** important means of meeting the problem of crowding in GSO, large communications platforms (LCPS), on which several transmission facilities are mounted together, are a promising new configuration of technology. In addition to fixed and mobile communications an LCP may provide direct broadcast, navigational, meteorological, and Earth observation services, and support for scientific payloads, thus becoming a multimission platform. The large capital expenditures and the number of technological advances re-

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[13] Elizabeth L. Young, **statement before the** Subcommittee on Space Science and Applications of the Committee **on Science and Technology, U.S. House of Representatives, 97th** Cong., **1st** sess., July **10, 1981, pp. 122-123.**

quired make LCPS a much more speculative prospect than are 30/20 GHz satellite systems.

In general, an LCP is distinguished from conventional communications satellites by greater capacity, connectivity, and switching capability. The LCP would provide high capacity by means of multiple spot beams and multiple bands. It would provide good connectivity for a wide range of communications users, and it would offer very substantial in-orbit switching capability, far beyond that attainable by conventional satellites.1[4]

The use of LCPS would bring several substantial changes:

- The high power of the platform would drastically lower the power needs and therefore the cost of the ground segment, resulting in a proliferation of Earth stations. Space segment costs per channel would drop, despite the larger initial investment required.
- The large capacity of the platforms would result in a requirement for fewer slots in the geostationary orbit. This would relieve the congestion that would result from the use of conventional satellites.
- The switching capability of the large platforms would eliminate the need for complex switching at the Earth stations. Earth stations would no longer be required to access more than one spacecraft.ls

The cost savings for LCPS, estimated to be substantial,[16] would result from three areas in which economies of scale could be achieved. These economies result from:[17]

- reduced mass in orbit:
  - –lower bus mass per pound of payload, and
  - —much lower payload mass to perform the same mission,
- slightly lower production cost per pound of hardware, and
- . much lower transportation cost per pound
  - —more efficient utilization of shuttle capacity.

The critical need of the satellite communications industry of the 1990's will be a spacecraft capable of supporting the large multi beam antennas and switches needed to provide large-scale frequency reuse for point-to-point services. A large platform in GSO is ideally suited for this task. All other services provided by the platform must be compatible with this primary mission–i.e., they must not interfere with or compete for bandwidth with the point-to-point payloads.[18] The primary and secondary services of LCPs in geostationary orbit may be broken out as follows:[19]

Primary use:

- Fixed ***point-to-point services:***
  - –direct-to-user (DTU) or customer premise services (CPS) network, and
  - –high-volume trunking (HVT), domestic, regional, and international.

Compatible services:

- ***mobile services:***
  - —air mobile,
  - —sea mobile, and
  - –land mobile,
- ***Broadcast and relay services:***
  - –TV distribution (separate Ku-band allocation,
  - —educational TV,
  - –direct-to-home TV,
  - —tracking and data relay, and
  - –data collection.

DEVELOPMENT REQUIREMENTS

The development of large space platforms would require a significant number of technical accomplishments, though what has to be done to make them successful is, as theory, well-understood. Thus, they represent significantly more than a relatively larger step in the evolutionary pattern that satellites have always followed–from smaller to larger, from less to more reliable.

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[14] Future Systems Inc., **Large** *Communications Platforms Versus Smaller Satellites,* **prepared for NASA Headquarters, February 1979, p. ii.**

[15] Ibid., **p. 203.**

[16] Ibid., **pp. 203-204.**

[17] General **Dynamics, Op.** cit., Pp. 8-15.

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[18] **Ibid., pp. 8-44.**

[19] Ibid., **pp. 8-45.**

There are definite prerequisites that can, for the forseeable future, be provided only by the United States. First of all, the shuttle itself must be brought to operational status. Second, a vehicle capable of transferring a platform from low Earth-orbit (LEO), where its components would be brought up on several shuttle flights and then assembled, to its destination in GSO must be developed and proved. Third, satellite servicing and construction techniques (including extensive life-support and extra-vehicular activity (EVA), will have to be developed and demonstrated by NASA in LEO before the private sector will consider deploying LCPS in GSO. Next, certain improvements in the technology for the platform itself are needed. Of these, one is the design of antenna beams capable of very accurate pointing; this project, however, is an extension of present technology. Another is the development of a high-speed, low-power switch to interconnect the several antenna beams. Finally, the general requirements of long life and high reliability must be assured to compensate for the much greater expense of an LCP.

The requirements of long life and high reliability could be met in two ways. Either the hardware might be constructed to maximize these characteristics, or it might be deemed more feasible to rely on in-orbit maintenance of the platform. Maintenance, in turn, might be accomplished robotically by, for example, NASA's projected teleoperator, a remotely controlled device that would replace certain modules aboard the platform. Alternately, a manned orbital station in LEO, which might be deployed in 1990-2000, could be assigned maintenance duties; personnel would be dispatched to a platform on a transfer vehicle, not only to replace modules, but, if necessary, to make more extensive repairs. All of this must be accomplished at GSO and will require substantial development for an upper stage and for the shuttle itself.

LAND REMOTE SENSING BY SATELLITE

Issue 5: What Role Should the Federal Government Play in Developing or Operating a Satellite Remote-Sensing System?

Characteristics of Satellite Remote Sensing

Satellite remote sensing is one component of a broad range of technologies and techniques that are used to acquire data about the Earth's resources. They range from simple direct human observation and measurement, to high-altitude aircraft photography, to sensing by satellite. Thus, satellite remote sensing exists as one element of an activity that has been part of the human scene since it first became desirable to survey the extent and kind of resources available for human use.

Satellite sensing has unique properties that separate it from earlier methods: ease of operation, once established; the ability to see other lands without intruding in the country or its airspace; the ability to sample very large areas in a single "scene"; and the ability to produce an enormous data flow in digital form suitable for direct computer processing. Unlike other methods, its development and present operation rest solely with the Government.

Each of these characteristics, as well as others that will become apparent in the ensuing discussion, present new opportunities to the traditional users of remotely sensed data, but they also raise issues that must be resolved before satellite remote sensing can become a large and thriving component of resource observation and development.

Current Status of the U.S. Land Remote-Sensing Satellite Program

The world's first civilian land remote-sensing satellite was launched by NASA in 1972. Originally named the Earth Resources Technology Satellite (ERTS), the name was later changed to Landsat 1. The Landsat 1 and Landsat 2 satellites no longer provide data to users. Landsat 3 functions only partially. The present sensors are a multispectral scanner (MSS) that can sense the surface of the Earth in four different spectral bands, each with 80 m resolution, and two television-like cameras called return beam vidicons (RBV). Used together, the two sensor systems can produce data products that achieve 30 m resolution. The data from Landsat are transmitted to Earth by radio link and received at some 12 stations located in various countries around the world (fig. 6). The MSS sensors aboard Landsat 3 are returning only partial data, though the RBV sensors are functioning normally. A new satellite, having a broad resolution, high spectral coverage sensor called a thematic mapper (sensitive to emissions in seven spectral bands) is scheduled for deployment in late summer 1982. This satellite is designated Landsat D. A second satellite with similar sensors, Landsat D', has been scheduled for launch in 1985.

Although the system has been an R&D system designed to verify the potential of satellite remote sensing, through the efforts of NASA, the data from Landsats 1, 2, and 3 have attracted a wide variety of users (resource managers) in this country and abroad. These users consider Landsat data to be an invaluable component of the larger realm of resource inventory data from all sources (see apps. B and C for details). For some, data from Landsat have become a baseline requirement of their daily routine. For others, these data serve the secondary, but important role of a comparison data base. Generally, the users treat Landsat as if it were an operational system, even though it is still officially an R&D system managed by NASA.[20]

Although the system has found a variety of users, it has yet to demonstrate that it can attract a large enough market for satellite data to support even the management and operations of the system without large Federal outlays. Part of the problem is simply one of technological maturity. Very few technical improvements have been made in the characteristics of the data available from Landsat since 1972.[21] Many applications will require a satellite system of greater capability: higher spatial resolution, stereo imagery, and broader spectral coverage. A more important reason Landsat has not attracted a larger number of customers, however, is the uncertainty about whether the Landsat system will continue.

Many users of remote-sensing data from civilian satellites express considerable frustration with the current U.S. program. Though it is at a relatively primitive stage, the technology is far ahead of the institutional arrangements necessary to collect and distribute the data in a timely and predictable manner. From the users' viewpoint, the program is in disarray, and is characterized by a lack of clear direction and by organizational ambivalence.[22] According to U.S. policy, as articulated in the Carter administration's Presidential Directive 54,[23] NOAA will be responsible for managing civilian operational land remote-sensing activities after the multispectral scanner aboard Landsat D becomes operational in January 1983. NASA will remain in charge of R&D of satellite remote sensing for the civilian sector. This administration, as well as the previous one, is committed to transferring land remote sensing by satellite to the private sector. The current policy is to make this transfer "as soon as possible."[24]

Criteria for a Satellite Remote-Sensing System

Regardless of who operates a civilian satellite land remote-sensing system, the Federal Government or the private sector, the major users of satellite data have basic general needs for the conduct of an operational system, needs which they have expressed clearly.[25,26] Because each user has specific data needs (e.g., resolution, spectral ranges) closely related to his applications, each will have a different view of the specific technology most suitable for his purposes. However, given an operational system for acquiring remote-sensing data by satellite, most users agree on the following minimal criteria:

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[20] "Planning for a Civil Operational Land Remote Sensing Satellite System: A Discussion of Issues and Options," Department of Commerce, June 1980.

[21] "Department of the Interior Position paper on the Private Sector Transfer of Civil Land Observing Satellite Activities," Department of the Interior, October 1981.

[22] "Remote Sensing Government User Concerns," OTA Workshop, May 1981.

[23] Presidential Directive 54, White House Press Release, Nov. 20, 1979.

[24] J. Wright, Department of Commerce statement, U.S. Senate and House of Representatives hearing on Civil Land Remote Sensing Systems, July 22, 1981.

[25] OTA Workshop, op. cit.

[26] U.S. Senate and House of Representatives hearing on Civil Land Remote Sensing Systems, July 22 and 23, 1981.

- **Continuity of data flow.** Reliable, continuous flow of data is regarded by operational users as mandatory. For each user, the term "continuous data flow" has a slightly different meaning. However, it generally means being able to acquire the data that a satellite could have taken, or did take, in a timely manner appropriate to a given application. In the past, the data flow has been interrupted or slowed by failure of the tape recorders on the satellites, a natural enough occurrence in an R&D system but unacceptable in an operational one. Therefore, in order to ensure continuity, the users need the most reliable possible system, consistent with obtaining the necessary data. A backup satellite for deployment should the first satellite fail in a major way is also an important requirement.

  Delivery of data to the user has also been interrupted or slowed by the inability of the data center at NASA's Goddard Space Flight Center to process Landsat data fast enough.[27] Domestic users have experienced delays of up to 6 months in the delivery of Landsat data. Certain time-dependent data needs, such as those of agriculture or pollution control programs, cannot be served if the data cannot be processed within a few days (see table 2). The work of other programs is also slowed considerably by such delays.

  Continuity of data also means retaining data acquired in previous years. Landsat satellites have provided data since 1972, when the first remote-sensing satellite was launched. The data are stored on magnetic tapes that deteriorate over time. Thus, the tapes must be rerecorded in order to save the data. Because of the storage problems involved with saving everything, the EROS Data Center has selected standard scenes of cloud-free data over the world. The NASA Goddard Data Center is transferring these scenes from the early tapes to the computer compatible tapes (CCT), that will be stored at the EROS Data Center and available upon request to users. In the course of identifying the scenes to be saved, the EROS Data Center notified users of Goddard's intentions and asked them to suggest which scenes to save. Some early data, which are currently being stored at Goddard, are scheduled for destruction. However, for many users, these early observations represent a valuable and irreplaceable baseline for comparison with later observations. In addition, much of the only cloud-free global coverage dates from this early period in space remote sensing. Users agree that it is important to retain these early data and make them available upon request. They represent a large investment and a valuable global resource for the future.

  Looking toward the future, the users of Landsat data are concerned that data will not have begun flowing from Landsat D before the flow from Landsats 2 and 3 ceases. Will Landsat D be available soon enough to assure continuity of the data flow? There are presently no plans for backup should D fail to operate as planned.

Table 2.—Data Needs of Foreign and Domestic Users

- *Agriculture* **(Federal, State, and private): specific sampling areas** chosen according to the crop; time-dependent data related to crop calendars and the weather patterns
- Forestry (Federal, State, and private): specific sampling areas; twice per year at preselected dates
- Geology and nonrenewable *resources* (Federal, State, and private): wide variety of areas; seasonal data in addition to one-time sampling
- Civil *engineering and land use* (State and private): populated areas; repeat data required over scale of months or years to determine trends of land use
- Cartography (Federal, State, and private): all areas; repeat data as needed to update maps
- Coasta/zone *management* (Federal and State): monitoring of all coastlands at selected dates depending on local seasons
- *pollution monitoring* (Federal and State): broad, selected areas; highly time-dependent needs both **for routine monitoring and in response to emergencies**

SOURCE: Off Ice of Technology Assessment.

- ***Quality and integrity of data.*** It is important that data acquired in different time periods be comparable and of uniform quality.

  Landsat data are initially "preprocessed" at Goddard; the results are in the form of high-density digital Tapes (H DDTs). These HDDTS are then sent to the EROS Data Center for processing. EROS in turn supplies data to users either in the form of film imagery or as CCTS. Some additional special process-

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[27] OTA Workshop, op. cit.

ing of data to meet particular user needs is done at EROS; other similar processing is done by various value-added companies.

Four problems have surfaced in the data stream from satellite to user. First, the quality of data tapes is not always maintained at a high level. Users complain that errors introduced in the HDDTs from Goddard are passed through and appear in the CCTS from EROS. Second, abrupt changes over time in the format of CCTS, again a function of the R&D nature of the system, have seriously inconvenienced users. These changes have made it impossible to process older CCTS with the techniques for processing current CCTS. Users must therefore go to unanticipated and sometimes extraordinary lengths to process the earlier tapes. These format changes were made without sufficiently consulting the needs of the user community. Thirdly, not all users want to purchase preprocessed data because preprocessing necessarily causes some degradation of quality or loss of information. For some applications, it is better to have raw data as they come off the spacecraft. Finally, maintenance and management of the data base have been inadequate.

- ***Adequate collection of primary data.*** For a truly global satellite remote-sensing system, all data must be collected.

  As the example of Costa Rica illustrates (see below under "Foreign Uses of Landsat Data"), the United States lost an important opportunity to sell Landsat data because Costa Rica is just out of range of receiving stations and because Landsat 3's tape recorders are unreliable. The tracking and data relay satellite system (TDRSS), when it is completed, will serve to gather and relay data from Landsat D and D'. Until then we will be dependent on foreign ground stations for MSS data received by D and D', because these spacecraft will carry no tape recorders. Although the U.S. agreements require the foreign ground stations to make their data available to others in accordance with our open data practices, it is not clear that the foreign ground stations will respond to requests for data in a timely and efficient manner. Users in some countries, including the United States, have experienced difficulties in the past in obtaining needed data quickly from foreign ground stations.

- ***Adequate consultation with the user community.*** This is an essential element of an operational space remote-sensing system, whether run by the Federal Government or by the private sector.

  Although NASA has consulted other Federal agency users, neither users in the private sector nor those in State and local government have been included in any way in the key decisionmaking processes. A successful operational system depends on the full participation of all elements involved on an ongoing basis.

  In an effort to build interest in the capabilities of Landsat, NASA has sought the advice of the user community about its needs with respect to sensors and resolution limits. However, as maybe appropriate in an R&D system, NASA has approached the problems of the future orbital height, orbital planes, and orbital path of the Landsat D satellite from the point of view of optimizing spacecraft design, rather than the data product. This approach will result in abrupt changes in data format and further disruption of the data base, to the discomfort of the potential purchasers of the data from Landsat D. Consequently, the user community displays considerable skepticism about the Federal commitment to operate a complete land remote-sensing system via civilian satellite, tailored to providing standard and predictable data products for the public and private organizations that are attempting to integrate Landsat data into an ongoing operation,

- ***Continuation of remote-sensing R&D.*** The current Landsat capabilities, though they satisfy the basic needs of a large portion of the potential users, are also limited.

  Users such as those represented by the Geosat Committee[28] are very interested in using stereo images of the Earth for exploration of mineral and energy resources. Geosat has suggested development of the so-called

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[28] "Satellite Remote Sensing Data–An Unrealized Potential for the Earth Science Community, the Geosat Committee Inc., 1977."

“stereosat” remote-sensing satellite.[29] Cartographers would benefit from stereo imaging and from higher resolution. Many other users agree that an automated mapping satellite system based on multilineal array technology (MLA), a so-called “MAPSAT,” would serve their needs for high-resolution (20 m)[30] stereo imagery as well as their multispectral and spatial requirements ***and*** be far cheaper than Landsat D or D’,[31]

Even the heavy users of current Landsat data will find their needs expanding as they gain experience with the data and understand their potential. They are likely to find needs for data from new sensors and advanced data relay subsystems.

- Price ***of data.*** The major concern of the users with regard to price of data is that inevitable price increases be reasonably predictable and incremental.

  Current data prices are much lower than the marginal costs of generating the data. Users recognize that future data prices will be higher as the prices are increased to reflect marginal costs. However, users would not purchase the same volume of data if the prices were doubled or tripled suddenly. Some State and local government users also face the difficulty of a 2-year budget cycle.[32] If data prices are raised precipitously, these users cannot adjust to the increase for up to 2 years, and will be forced to purchase fewer data products than their needs would actually dictate. At a minimum, there should be a declining Federal price subsidy to bridge the gap in budget adjustment.

On the whole, these are not hardware or technology problems, but rather derive from the management and structure of the system. The larger problem, at least in part, seems to be that NASA, in an effort to test a broad spectrum of applications and to interest potential users around the world in using remote-sensing data, created a de facto operational system.[33] Its effort was driven, in part, by a desire to justify the R&D program to OMB. However, being by established policy an R&D, not an operations agency, NASA has not been able to manage or fund an operational system, and has therefore been unable to guarantee its continuity. Nor was NASA directed to assume operational responsibilities by the President or the Congress. NOAA, in turn, is not scheduled to assume the management of the system until 1983 (after Landsat D is launched). Circumstances such as these have made the users extremely wary of investing in the manpower, hardware, and software to process Landsat data, Further, these uncertainties have limited the size and vitality of the market for Landsat data as well as that of the private data-processing (value-added) industry.

In short, the future direction of satellite land remote sensing has reached an impasse: the users refuse to invest further in Landsat data because the system is not operational, but many of them also oppose changes because they have become dependent on the system as it is currently configured. On the other hand, no existing institution, Federal or private, seems appropriate to undertake operations: first, because there are not enough users, and second, because the present system is not advanced enough to generate a **large** market. Among other things, this has led to a situation in which the French, using technology originally developed in this country, will shortly provide very strong commercial competition in land remote sensing. They have designed their SPOT system from the first to be an operational system and have included user needs in the system specifications.

Foreign Users of Landsat Data

One of the basic tenets of the 1958 NAS Act is that “activities in space should be devoted to peaceful purposes for the benefit of all mankind.”[34] Our Landsat system, with receiving stations distributed around the world and a prac-

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[29] Ibid.

[30] A. P. Colvocoresses, “Proposed Parameters for Mapsat: Photogrammetric Engineering and Remote Sensing, ” vol. 45, No. 4, pp. 501-506, April 1979.

[31] Itek Corp., final report, “Conceptual Design of an Automated Mapping Satellite (Mapsat), ” January 1981.

[32] B. Rado, statement to U.S. Senate and House of Representatives, hearing on Civil Land Remote Sensing Systems, July 22, 1981.

[33] P. Mack, “Space Science for Applications: The History of Landsat.’ in *Space Science Comes of Age,* P. A. Hanle and V. D. Chamberlain (cd.), Smithsonian Institution Press, 1981.

[34] National Aeronautics and Space Act of 1958, op. cit.

tice of open data sales, certainly satisfies the injunction of the NAS Act. It also satisfies section 102c (7) of the act, directing "cooperation by the United States with other nations and groups of nations in work done pursuant to this act and in the peaceful application of the results thereof." In fact, from a pure cost-benefit approach, remote sensing by satellite only makes sense as a global system. For the continental United States alone, the investment in Landsat far exceeds the cost of obtaining equivalent data by other means. However, U.S. corporations and Government agencies also need foreign data in order to pursue their operations abroad. More importantly, Landsat, by providing low-cost images of the world to all purchasers, has enhanced our status in the world. Our willingness to join others in solving problems of regional or global import cannot but strengthen our overall position in the world as a leader concerned for the good of all.[35]

Importance of Landsat Data: Three Asian Countries

Foreign users of Landsat data have found them very helpful for problems of resource management and control. The experiences of several Asian countries illustrate the potential of Landsat for these uses. Asia serves as an excellent example because it is the location of five of the original 10 countries selected by the U.S. Agency for International Development (USAID)S6 in 1975 for initial testing of the applicability of using Landsat data for resource management problems in developing nations. Two criteria have to be met for this technology to be successful in resource management applications: a practical means of transferring it to the country must be found, and the data flow should be maintained over an extended time. A brief historical review of three of the original Asian programs and their present day applications provide insight into the ability of Landsat to meet these criteria.

Bangladesh began its use of Landsat data with the help of USAID. This Asian country was interested in testing the use of Landsat data for deriving information on agricultural production and land use in order to promote optimal development of a section of northeastern Bangladesh. The initial project was quite successful and regional information on rice and other crop production was obtained during the 1975 winter season. Interpretation of Landsat data during this project also provided detailed information concerning changing pond, stream, and flood patterns, data that are invaluable for planning at both regional and village levels.[37] After this initial introduction of Landsat technology, its use in Bangladesh has rapidly expanded with diverse government programs in agriculture, forestry, oceanography, fisheries, and disaster prevention. In 1980, in an effort to enhance the return from this effective and developing technology, Bangladesh established the Space Research and Remote Sensing Organization (SPARRSO), a lead government agency for R&D and operational activities.[38]

Sri Lanka is an island nation whose economy is highly dependent upon agricultural production. Because of such constraints as the rugged topography and its effect on transportation, as well as a paucity of trained field personnel, continual effective ground survey of agricultural production is not feasible on a continuing basis. In 1975, the Ministry of Agriculture and Lands requested USAID assistance for establishing local capability to use remote-sensing technology for accurate agricultural inventories. Specifically, the Ministry requested assistance in digitally processing Landsat data. This project resulted in the development of an operations manual and digital analysis capability in that country. Although the accuracy was less than would be desired in a mature program for estimating agricultural acreage, Landsat was recognized as a valuable resource management tool, and in 1978 a national remote-sensing center was established.~ USAID

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[35] C. K. Paul, and A. C. Mascarenhas, "Remote Sensing in Development," *Science, vol.* 214, No. 4517, 1981.

[36] T. W. Wagner, and D. S. Lowe, *AID's Remote Sensing Grant Program* (Ann Arbor: Environmental Research Institute of Michigan, 1978, pp. 11-22).

[37] M. A. H. Pramanik, and A. K. M. Alam, "Space and Remote Sensing Activities in Bangladesh," proceedings of the Second Asian Conference on Remote Sensing, Beijing, China, 1981, 1-2-l.

[38] T. w. Wagner, op. cit., pp. 69-81.

[39] Christopher Nanayakkara, "The Sri Lankan Experience in Remote Sensing, " proceedings of the Second Asian Conference on Remote Sensing, Beijing, China, 1981, 1-7-l,

[40] V. Geiser, M. Sommer, and E. Nanayakkara, *The Sri Lanka/Swiss Satellite Imagery Interpretation Project: Report on Test Phase* (Colombo: Center for Remote Sensing, 1981).

provided a followup grant in response to a Center request for the development of a simplified low-cost Landsat data-processing system to address specific resource needs. This system will be delivered to the Center in 1982. A unique program also currently under way in Sri Lanka reflects the value that another industrial nation places on the application of U.S. space-derived data for development assistance. The Swiss are training Sri Lanka resource managers in techniques for using U.S. Landsat data for monitoring rice production. Sri Lanka is also using remote-sensing data for monitoring land use and for mapping its forest cover. Sri Lanka views Landsat as a successful technology that can be employed without heavy capital investment if the project is well planned, and is optimistic about the possibilities for using future satellites.[41]

Thailand began its leadership role among the developing nations of Asia by establishing a national remote-sensing program in 1971. The major goal of Thailand's program was to develop the means to use remote-sensing technologies effectively for natural resource management. As a result of its early initiatives, Thailand's Royal Forestry Department was one of the first departments of any country to develop an operational Landsat-based system for monitoring deforestation. Today, information derived from Landsat data is a major component of the forestry policy decisions of this Asian nation.[42] USAID'S 1975 joint project with the Thai agricultural department that sought to obtain acreage information as part of the annual rice, corn, and sugar cane survey was of limited value. Two major constraining factors affected this project: 1) continuous cloud cover during scheduled sampling periods and prior to harvest prevented data acquisition by Landsat; and 2) the available Thai computers had not been programmed for Landsat data analysis prior to terminating this project.[43] However, the USAID project was beneficial in providing experience with Landsat sampling and data analysis techniques. This experience contributed to later successes such as the national rubber plantation survey and a continuing soil erosion study by the agricultural department. Landsat data are being widely used by other government agencies, including the Department of Mineral Resources and the Royal Irrigation Department. Thailand is completing a major Landsat/Metsat ground receiving station that should provide timely data to the Thai user service center beginning in late 1982. Thailand has not only committed itself to using data from Landsat, but it has also shown its determination to assist other Asian countries. Data from this ground station will be made available to these nations.

These selected Asian cases demonstrate the utility of Landsat technology for peaceful uses and its applications to the resource management problems of developing nations. Landsat technology has not only been successfully introduced, but has been shown to be effective in monitoring resources over time, These factors make it an effective tool in global resource development. One must remain cognizant that Landsat technology, although transferable to developing countries, is not a simple technology. **It** therefore demands complex man/computer interaction and timely current data for the analysis of most renewable resource problems.

However, though foreign users of Landsat data have made good use of them, they often face problems very similar to those troubling domestic users. The experiences of an Italian land planning firm are not atypical of user experience in the United States and abroad[44]. This firm attempted to integrate Landsat data into its normal data stream from aircraft and ground survey. After first learning how to make the best use of the data, it then experienced difficulties in obtaining timely data and data that were of high quality. As a result, it has made much less use of Landsat data then originally planned. Instead of being a major component of the firm's land planning efforts, these data serve only a secondary role in its total scheme.

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[41] Christopher Nanayakkara, **"The Sri Lankan Experience in Remote Sensing, " proceedings of the Second Asian Conference on Remote Sensing, Beijing, China,** 1981, **1-7-6.**

[42] Sanga Sabhasri, **pradisth** Cheosakul, **Boon Indrambarya and Suvit** Vibulsresth. **"National Remote Sensing Activities in Thailand," unpublished report to the Second Asian Conference on Remote Sensing, Beijing, China, 1981.**

[43] T.W. **Wagner, op. cit.,** pp. 77-81.

[44] **G. C. Bernardino, "European Industrial Space Projects, " American Astronautical Society, 19th Goddard Memorial Symposium, March** 1981.

A short case history of one country's attempt to use Landsat data will illustrate other problems foreign users have faced. It also provides another illustration of the usefulness and cost effectiveness of Landsat data for attacking important renewable resource problems.

Importance of Landsat Data: Case of Costa Rica

Deforestation and subsequent desertification have become problems of great concern in many countries throughout the world. The case of Costa Rica demonstrates the importance of Landsat data for dealing with these problems and the potential tragedy of unavailability of these data through discontinuity in Landsat service.

The Government of Costa Rica (GOCR) Ministry of Agriculture was aware in the early 1970's that loss of forest cover and watersheds had become a major problem. Personnel in the ministry knew that a complete forest inventory would be necessary in order to assess the extent of the problem, but that if contemporary ground truth and survey methods alone were used, 25 years would be needed to complete the inventory. By that time, there might be no forests to save. Recognizing that the problem was beyond the capabilities of his staff, the Minister of Agriculture requested assistance from the USAID to determine whether Landsat technology could be applied effectively to map the resources of Costa Rica. USAID commissioned a study that was completed in March 1977.[45] This initial study concluded that the deforestation problem was even more severe than GOCR had thought, and that a combined aircraft and satellite remote-sensing program might be the most cost-effective way to determine the full extent of the problem. Data from Landsat could not alone do the entire job because some areas (the watersheds most at risk) required detailed mapping and analysis at scales and resolution beyond the capability of the current Landsat series.

As a second step in determining the feasibility of relying on Landsat data, USAID contracted for a test and demonstration project, which was completed in March 1978.* The principal conclusions for the forest sector were the digital-processed Landsat data would be the most cost-effective alternative for "Level I" forest cover maps at a scale of 1 :200,000, and that color infrared (CIR) photography would be the best choice for "Level 11" and Level III" mapping. Landsat data could also be used effectively for urban mapping and analysis, but would be cost effective only if coupled with a project to maintain the forests that would absorb the primary costs.

The major problem confronted in the second phase of the project was that of obtaining "current" Landsat data. After an initial request to NASA was ignored, it was necessary for the President of Costa Rica to make a direct personal request to the White House in order to have the tape recorder aboard Landsat 3 activated, so that data on Costa Rica could be collected, stored, and relayed in a timely fashion.

The third phase of the Costa Rican study was the pilot project (conducted between January 1978, and June 1979).47 Here the objective was to develop in Costa Rica an operational system for resource management. The system was to be tested and established on a cross-sectional area representing more than 20 percent of the entire country and running from the Caribbean to the Pacific. This project demonstrated that a nationwide program based on CIR photography and Landsat data was both possible and practical. Such a program would be remarkably cost effective: the entire forest survey task could be accomplished in less than 3 years for about $1 million (compared with the earlier GOCR estimate of 25 years and $20 million, using only ground and aircraft surveys.)

Despite the clear need for such a nationwide program in Costa Rica, despite its cost effectiveness, and despite significant investments both by GOCR and by the United States, today–3 years later—no system to use Landsat data is yet

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[45] "An Assessment of Resource Inventory and Environmental problems in Costa Rica," Report to USAID, Office of Development Resources, LA/DR, contract No. AI D/afr-c-1 135-8, March 1977.

a"The Utility, Cost, and Effectiveness of Remote Sensing for Forest and Urban Sector Assessment in Costa Rica, report to USAID/ROD/LA/US and USAID/Costa Rica, contract No. AID/afr-C-1 135-9-10, March 1978.

[47] " Design of a Natural Resources Inventory and Information System for Costa Rica: The Pilot Project Report, " report for USAID, contract No. AI D/la-C-l 253, June, 1979.

in place in Costa Rica because of the unreliability of the present Land sat system. The system for deforestation analysis does not exist because sparse data were supplied and because the United States made no credible assurance that continuity of data would be maintained in the future. During the entire period of the pilot project (January 1978 through June 1979), only six images were obtained over the western half of the area and only two over the eastern half. Wet-season data were never obtained, and no CCT was ever available for the one usable image over the eastern section. On the basis of this experience, GOCR decided not to fund a nationwide operational program.

Many of these user problems are due to the R&D nature of the current system, but they point up the care that will be needed in planning for a future operational system, whether operated by the government, the private sector, or a mix of both.

Market for Satellite Remote-Sensing Data

Whatever entity (ies) operates a U.S. satellite land remote-sensing system, the size and breadth of the market for the data it supplies is of major concern. in either case, recovery of the costs of investment and upkeep (particularly those of the space segment) is necessary. In a publicly owned system, political benefits, such as its use as a tool of foreign policy or its value in enhancing U.S. technological superiority, may justify a reasonable shortfall in cost recovery. But in a privately owned system operating with no taxpayer subsidy, the market alone must bear the entire burden of recovering these costs.

The market for remote sensing data from space divides naturally into two categories: The market for ***primary data*** provided directly from the space segment, and the much more lucrative market for ***value-added data,*** which represents the largest part of the ground segment. Based on its review of the size and nature of the market,[48] OTA can make the following observations:

- Size ***of the market.*** The true extent of the market for primary satellite remote-sensing data is unknown. The domestic market consists of two kinds of users, the government (local, State, and Federal), and the private sector. Federal Government users generate the largest demand in this category today. Although the records of the EROS Data Center and the NASA Goddard Distribution Center indicate a relatively small primary market (approximately $5.7 million per year sold by the United States directly)[49] this estimate reflects only a portion of the true market, which could be at least as much as 50 percent greater. Some users obtain data directly from other users at a portion of the original cost, or gratis (i.e., a certain amount of data sharing occurs).[50]
- Even if the exact distribution of original satellite data were known, however, it would represent only a fraction of the value of data after they are computer-processed to provide particular information. For example, the cost of a CCT is currently $200 to $300. To process the data contained on a specific CCT and to present it in usable form to the ultimate user of the data can cost between $1,000 and $20,000, depending on how much information is extracted from it or merged with it, and the number of steps taken to enhance the original information. Processing satellite remote-sensing data thus represents a significant investment opportunity for a firm, especially one that is already capable of digitally processing remote-sensing data from aircraft. Currently, some 60 firms are known to be capable of processing Landsat digital data. Another 35 firms (28 United States, 7 foreign) sell computer-processing equipment for Landsat, which range in price from $50,000 to $500,000. Firms providing digital processing of photographic data might also be interested, because the basic techniques for enhancing image data by computer are similar for all applications, though most film processors would lack the analytical expertise in land resources.
- Nature ***of the market.*** One of the major difficulties in defining the full extent of the

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[48] "Commercialization of Remote Sensing, " OTA Workshop, May 1981.

[49] "Status of NASA's Landsat—D," GAO briefing, July 1981.

[50] "Commercialization of Remote Sensing, " OTA Workshop, May 1981.

market is its extremely diffuse and dispersed condition. Each major category of user, both foreign and domestic, has different spectral and resolution requirements, is interested in different geographical areas, or needs data on a different time schedule. Table 1 summarizes the categories of major users and their general needs for Landsat data.

In order to understand fully the data needs of each user group, it would be necessary to analyze in detail the records of the EROS Data Center, the NASA Goddard Data Processing Center, and the foreign ground stations to determine:

- Who uses the data (specific users identified by discipline)?
- What regions are requested? With what frequency? Under what time constraints?

From this information and a projection of user requirements, future market potential might be determined. Predictions about new markets, foreign and domestic, would have to be added to this information to reach an estimate of the total size of the market for Landsat data. To OTA's knowledge, no analysis has reached the level of detail required for making reasoned decisions about the potential for commercialization of the technology,

Commercialization of Remote Sensing: Domestic and Foreign Concerns

If commercialization of civil land remote-sensing satellite activities is to occur, the major questions before the country at this time are how and at what speed the transition to the private sector should be accomplished. Conversion from public to private ownership and operation of the civilian land remote-sensing system would affect the user community in a variety of ways. Users perceive that both advantages and disadvantages will result from the change. In addition to the concerns of users previously expressed in relation to an operational system, they have raised the following concerns specific to a commercial enterprise:

- Open data. The U.S. current [y supports and follows the practice that any party, regardless of nationality, may purchase Landsat data, regardless of the country from which they are derived. This conforms to long-standing U.S. policy on the sale of maps prepared by the U.S. Geological Survey. Users fear that this practice may be discontinued. The question of whether unrestricted dissemination of remotely sensed data violates the sovereignty of a sensed nation has occasioned vigorous debate in the U.N. and other forums for many years; no agreement has yet been reached. Many countries have objected on the grounds that they do not wish important information about indigenous mineral resources, crop conditions, or military activities to be made public. Private operation may heighten suspicion that such data will be used to enable interests outside the country to gain a competitive advantage, or that data may be sold secretly to political adversaries. These concerns will increase sharply as new sensors improve upon the current resolution of 80 m for the MSS aboard Landsats 2 and 3.
- Resolution limits. What regulations will be imposed concerning the limit of resolution of the sensors? The thematic mapper on Landsat D and D' will be capable of 30-m resolution. The SPOT sensors will reach resolutions down to 20 and 10 m. Will there be restrictions on dissemination of high-resolution data from some areas? For some applications (e.g., forestry), resolutions of 1 to 5 m over small areas would be useful. Further, as other users become more accustomed to the capabilities of remote sensing, and as their ability to handle massive amounts of data improves and costs decrease, they are likely to find need for data of higher resolution. As in other aspects of satellite remote sensing, users want to be involved **in the decision making process** for determining the limits to resolution. Resolution limits will also be of major international concern.
- ***Competition from governments.*** Both the potential operators of remote-sensing systems and the value-added firms are concerned about potential competition from governments, either the United States or foreign entities. For example, NASA may

now compete with private industry when it institutes an R&D project in a university or government facility to process Landsat data. These projects often result in computer software that competes directly with software packages developed by private value-added data processors.

- Price ***of data.*** The user community is quite concerned about the price of primary data from a privately owned satellite system. It fears a dramatic increase in price if total costs are to be recovered.[51] This is especially true for users who require repeat data on a time scale of weeks or months. For users whose needs are largely for one-time data from a particular region, the cost of a single CCT is not as critical. It is doubtful that the price elasticity is sufficient to allow prices to be raised to a full cost recovery level in the next few years,
- Continuing ***Federal R&D.*** users recognize that neither they nor the actual operators of land remote sensing are willing to provide the resources to fund continuing R&D in the private sector. Yet there are a number of technological improvements that could be made to the system even after Landsat D and D' are operational (e.g., stereo imagery, higher resolution, greater spectral coverage). Users therefore see the need for continued research by the Federal Government, and for substantial involvement by the user community in the decisions about the directions such research should take.
- ***Archived data.*** What will happen to the archived data that have already been provided by Landsats 2 and 3, the shuttle, Skylab, and other means if the private sector assumes responsibility for U.S. satellite remote-sensing activities? As mentioned earlier, users are very concerned that the previous data be retained. But retaining them is very costly because the high-density digital tapes have a limited lifetime and, therefore, must be recopied at regular intervals.

Foreign Policy Concerns

W/hat commitments does the United States have to foreign purchasers of Landsat data if the entire system is in private hands? Other countries, particularly LDCS, are well aware that the possession of remote-sensing data carries with it the concomitant power to affect resource development. In considering transfer of Landsat or other satellite information systems to private hands, U.S. policy makers must consider the effects on our relationships with other countries. In addition, there is an added foreign and domestic problem of conflict of interest if a private corporate operator or its subsidiaries are allowed to offer value-added services. Advance knowledge of certain time-dependent data such as crop condition or water availability has the potential for exploitation by the firm before others could obtain the data.

The largest market for satellite land remote-sensing data might eventually be the totality of foreign users. if foreign governments are to depend primarily on U.S. satellite data, they will, in most cases, have to restructure any systems they presently use for monitoring and managing their resources. If the space and primary delivery system were publicly held, and if a country experienced problems with the pace of data delivery, or with the continuity or quality of data, it could then petition for redress directly through diplomatic channels. If the space and/or reception component were in private hands, such recourse could be only indirect. Competition from other satellite systems could mitigate this difficulty somewhat, if the data were totally compatible. Private operators would then have considerable incentive to meet contractual agreements. However, data from other systems (French, Japanese, or Soviet) will not be exactly compatible with those from the Landsat MSS. Will the U.S Government therefore regulate the sale of remote-sensing data to other states? If so, guidelines will have to be drawn up by an agency designated for the purpose.

Foreign users of Landsat data have purchased ground stations and data on the understanding that the system would be subject to possible data gaps, change of data format, and other deficien-

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[51] Joint **hearings, July 1981, oP. cit.**

cies peculiar to a system in development. According to the policy of the previous administration, however, they could look forward to data continuity through the 1980's. In light of the resolve to transfer Landsat technology quickly to the private sector, foreign users who have invested in Landsat receiving stations and data-processing equipment are questioning the value of our commitments. Total foreign investment in ground stations is about $60 million. Additional investments in data-processing equipment have also been made, as well as systems to integrate Landsat data with other necessary data. How will these ground stations and associated processing capabilities be integrated with a private system?

As sensors improve, the civilian capabilities for land remote sensing will grow uncomfortably close to military/intelligence standards. The satellites owned by the private sector will therefore require close supervision and oversight by the Government to: 1) monitor their technical capabilities, and 2) prevent use of the data derived from them inimical to the security of the United States.

Foreign Competition

Direct commercial competition to the U.S Landsat system will come from France's SPOT satellites starting in 1985, at about the time Landsat D' is now scheduled to be launched. The SPOT sensors will provide multispectral spatial resolution of 20 m, and panchromatic resolution of 10 m (compared with Landsat D's TM resolution of 30 m); in addition, SPOT will be able to "point" its sensors to the side, allowing it to acquire stereoscopic data. Unlike the more expensive and fragile optical-mechanical sensors on Landsat, SPOT will use relatively simple solid-state MLA. The establishment of a semiprivate company, Spotimage, to market SPOT data and services greatly enhances its competitiveness, especially in the absence of similar organizational certainty for Landsat; pricing for the two systems is not yet firm. Spotimage is heavily subsidized: the French Government has funded purchase and launch of the first satellite as well as all preliminary R&D, and owns the overwhelming majority of stock in the company. The first SPOT satellite will be launched in 1984 on the French launcher Ariane, and Spotimage is committed to maintaining an operational system for 10 years.

In the area of ocean surveillance, the Japanese Marine Observation Satellite (MOS) system is scheduled to begin operations in 1985. The satellite's sensors will be capable of observing land masses as well; this satellite is likely to be the precursor to an operational land remote-sensing system (for further details, see ch. 7).

Potential Policy Initiatives for a Land Remote-Sensing Satellite System

If the United States is to continue to play a role in the operation of a satellite land remote-sensing system, what mode of operation would be most desirable? OTA has explored a number of options for continued operation of a Landsat-type system (see ch. 10 for further details). Before a decision is made to proceed with any one of them, each option would require much more detailed study than it was possible to provide in this assessment.

- Designated ***private entity.*** The Government could ensure that its data needs were met by private operators by licensing a single U.S. entity to operate the satellite system. This could be done fairly quickly if a sufficient subsidy were provided, either through direct support for the difference between income and expenditures or through a Government guaranteed market.

  This option might suffer the objection from some foreign countries, particularly less developed countries (LDCS), that leaving the data distribution function in private hands might allow corporations from developed countries to use the resource information in remote-sensing data unfairly for their own profit. This objection could be circumvented if the licensed corporation were a separately incorporated firm prohibited from entering other fields; it would be, essentially, a regulated monopoly.

- ***Continued Federal operation of the space segment only.*** In this scenario, the Federal Government would continue to operate the space segment while turning over the distribution of preprocessed data to private sector operators. The rationale for such an approach is that the private sector cannot make a profit by operating the entire land remote-sensing system, but the Federal Government does not have the expertise to market satellite data effectively and promote their expanded use. Even if the relevant market experience could be obtained in the Government, Federal operation of an enterprise that the private sector might operate more efficiently would be inappropriate.

This option might meet with the same objection that private ownership of the entire system would, viz., that it gives too much power over resources to a private corporation.

- ***Laissez-faire private ownership and operation.*** The Government could declare that after Landsat D & D' reach the end of their useful life, it will terminate operation of land remote sensing from space (present administration policy) and leave the field open to all participants. The data needs of the U.S. civilian agencies would be filled by any supplier of satellite data, including foreign companies, and U.S. ground stations and related equipment would be sold to the highest qualified bidder or converted to other uses. The Government might be able to protect its future data needs by aggressive marketing of Landsat D & D' data in the expectation that a strong market **would encourage active private sector participation** in land remote sensing, or by using suitably degraded data obtained from reconnaissance satellites. As for the designated private entity option, the Government could provide the incentive for this option by guaranteeing a market.

  For the near term, however, a number of factors make this option the least likely to result in an operational satellite remote-sensing system:[52] 1) the market is likely to remain small enough that private ventures would sustain very high risk; 2) other, less suitable, but less expensive data alternatives are available (if full recovery of Landsat operating and maintenance costs is assumed); and 3) the largest benefits to accrue are likely to be public good benefits (i.e., the Government will remain the largest purchaser of data). Therefore, this option carries with it the danger that the U.S. data source will simply disappear if the private sector fails to find customers to cover the cost.

  If U.S. companies chose not to launch a satellite, or if the data taken by U.S. satellites were not of the sort or quality to meet the needs of mission agencies, the Government might be in the position of having to purchase data from the French or the Japanese.

- ***Broad-based cooperative arrangement.*** The United States could follow a policy that would include other nations in the ownership and operation of satellite remote sensing by setting up an international entity patterned after the interim INTELSAT agreement in which this country retained majority control for a specified period.

  Under this arrangement, a single management authority with multinational participation would assume responsibility for global operation of a land remote-sensing system, including establishing technical specification, procuring and operating satellites, and receiving and preprocessing satellite data. Such an approach would spread the investment risk, as well as encourage other nations to be more aggressive in developing their own internal markets for satellite data. It could also facilitate the eventual development of joint ocean remote sensing systems and lead to global systems that would join land, ocean, and weather data in order to monitor critical environmental factors. Perhaps the major advantages of this option are that it might well forestall wasteful competition among national entities and that it would provide an important forum in which international issues could be resolved within the confines of responsibility for an operational system.

  The major disadvantage of this approach is that the United States would no longer control its own system, still the only one in existence. U.S. users would face strong competition for their views in an organization that included other major users of remote-sensing data, and U.S. technology suppliers could no longer count on assured sales. Because of sen-

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[52] "Commercialization of Remote Sensing," OTA Workshop, May 1981.

sitive issues involving national sovereignty and resolution limits, the United States would have no guarantee that the resulting system would continue to serve U.S. needs as well as a U. S.-operated system. If the Landsat system is discontinued, however, a multinational entity, with its possible drawbacks, would be far better than the alternative of having to purchase data from Spotimage.

On the other hand, a multinational system might alleviate fears of the less developed nations that the industrialized nations will use their superior technology to exploit the resources of the LDCS. By buying shares in a multinational system, the LDCS would have the same access to data as any other country in the system.

- ***Continued Federal ownership.*** Although current policy is to transfer Landsat to private ownership, it would still be possible to reverse that decision and make a thoroughgoing commitment to a system owned and managed by the Federal Government. Meteorological satellites, which, like Landsat, provide data of benefit to the general public, have always been owned and managed by the Government. Unlike satellite communications, which is already fully commercialized, and materials processing in space, which, if successful at all, seems particularly appropriate for private-sector operation, satellite remote sensing could certainly be retained as a Government system on the grounds that the good it provides is primarily public. At the present time, about 50 percent of the data sold is purchased by Government agencies. The Government, in effect, makes the market.

  This comes about because most of the needs for data are for the management of renewable natural resources (e.g., agriculture, forestry, range lands). Even for those resources owned by the private sector, Federal and State government agencies set policies, quotas, and price supports on a regional basis that direct and constrain the management of these resources. Few private operators own enough land to find the expense of using Landsat data worthwhile, but the government agencies find the use of Landsat data highly cost effective for their functions (see the Bureau of Land Management and Foreign Agricultural Services case studies in apps. B and C).

As the last part of this section on land remote sensing argues, the data needs of the developers of nonreusable resources are large. However, even though the extractive industry finds Landsat data highly useful, its data needs will remain less than those of the managers of renewable resources simply because the latter require repetitive data. Therefore, in the Unites States, the majority user of data from a Landsat system is likely to remain the Federal and State Governments.

Potential of Land Remote-Sensing Data and the U.S. Economy

There is no doubt that satellite land remote-sensing data are useful for inventorying and managing the world's renewable and nonrenewable natural resources. Table 1 lists the areas in which satellite data are already being used in cost-effective ways for these purposes. Appendixes B and C illustrate the use two Federal agencies make of Landsat data. As emphasized above in the section on the data market, however, the variety of users and their different data needs, coupled with slow technical advancement and considerable uncertainty about the status of the Landsat system have acted to inhibit the market that many users[53] insist is there to be tapped.

Continuing to develop land remote sensing thus represents a certain economic risk for the Government or the private sector. If the market cannot sustain the investment, the losses could be great. However, the Government and private industry have already committed more than $1 billion to the Landsat venture. To fail to make the best use of these sunk costs represents a considerable loss as well. As the need to manage global resources efficiently and inexpensively grows with the expansion of the population, the need for a land remote sensing system increases proportionally. The use of Landsat data by Costa Rica is a case in point. For that country, use of Landsat data is not only the least expensive and

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[53] "Analysis of the Private Market for Landsat Products and Applacations," report by OAO Corp. for NASA contract No. NASW3358, 1981.

the most efficient way to monitor the rate of depletion of its forests, it seems to be the only means for meeting the problem in time.[54]

As large-scale forestry management methods improve, the worth of satellite-derived data will likely increase for domestic uses as well. The same is likely to be true for the other categories of table 1. However, perhaps the most critical area for the U.S. economy is in nonrenewable resources such as coal, oil, gas, and minerals. Even at the slower rates of energy consumption increase we have recently experienced,[55] our dependence on foreign petroleum sources has and will continue to be strong, primarily because our own recovery rate for oil will continue to decrease in the future.[56] Greatly increased exploration efforts will be needed to keep pace with the loss of U.S. reserves. Landsat data now play an important role in energy and minerals exploration, especially in regions where vast land areas must be evaluated. However, as far as the extractive resources industry is concerned, the use of Landsat data is still in its early development stages.[57] In spite of this fact, it is the largest single private purchaser of Landsat data. The extractive industry has now bought data covering from 10 million to 15 million square miles of the Earth's land surface. This is in spite of the fact that the current system lacks stereoscopic capabilities, nor does it gather the most appropriate spectral data for this industry's use.[58] Though it is difficult to assign a precise worth to the use of satellite data, because the process of exploitation involves a variety of techniques and often takes many years to achieve success, those who use the data are convinced of its usefulness and argue that if the present capabilities were increased, their task would be greatly simplified.[59] The support of an operational surveillance system tailored to mineral resources does not appear to be outside the financial capability of a consortium of resource companies, though there would be problems of competition between members of such a consortium to be solved.

The French SPOT system offers the sort of significant improvement in data capabilities that would be most useful to the exploration industry. However, American industry is reluctant to be forced to rely on foreign sources for their data, since it is unclear to what data they may or may not have access. Similar concerns apply to minerals exploration in this country and abroad. The question of what to do with the U.S. land remote-sensing system is a critical one for the future of the management and development of U.S. natural resources. Whatever is decided, the question should be resolved with dispatch.

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[54] " Design of a Natural Resources Inventory and Information System for Costa Rica," June 1979, op. cit.

[55] Weekly petroleum Status Report, U.S. Department of Energy, Energy Information Administration, Mar. 5, 1982.

[56] U.S. Congress, office of Technology Assessment, "World petroleum Availability, 1980-2000," technical memorandum, October 1980, OTA-TM-E-5.

[57] " Satellite Remote Sensing Data–An Unrealized Potential for the Earth Science Community," the Geosat Committee, Inc., 1977.

[58] Ibid.

[59] " Department of the Interior Position Paper on the Private Sector Transfer of Civil Land Observing Satellite Activities," U.S. Geological Survey, 1981.

MATERIALS PROCESSING IN SPACE (MPS)

Issue 6: What Are the Technological and Commercial Prospects for MPS?

The primary motivation for MPS research is to use the microgravity environment unique to space for scientific and commercial applications. process variables such as temperature, composition, and fluid flow may be controlled far better in an environment of microgravity. As a result, some materials can be manufactured in space with greater precision and fewer defects; others, which cannot be made at all on Earth, may become possible for the first time. MPS looks particularly promising for pharmaceuticals, electronic devices, optical equipment, and metal alloys.[60]

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[60] NASA, *Materials* Processing in Space: Early Experiments, Washington, D. C., 1980.

The U.S. civilian program has so far conducted rather limited MPS experimentation in space, and the results have been inconclusive.[60] if there are great days ahead for MPS, they must be preceded by years of research and major improvements in orbiting facilities.

Despite the need for further basic research, there may well be near-term opportunities for commercializing particular, carefully chosen technologies. Under a Joint Endeavor Agreement with NASA, the McDonneil Douglas Aeronautics Co., (working with Ortho Pharmaceutical) and the GTI Corp. are both moving vigorously ahead on R&D projects. Several other major corporations, including John Deere, TRW, INCO, and DuPont, have made significant commitments to early exploratory R&D. If MPS is found to be well suited to commercialization, several issues arise with regard to how and when it can be taken over by the private sector and by what means the U.S. Government can facilitate the transition.

Requirements for the Commercialization of MPS Technology

The space processing experiments that have been conducted so far have focused on identifying potential new processes and products. Because the research conducted to date has been basic, with subsequent commercial applications uncertain, there has been little private investment in this area. Private industry will invest its risk capital only if it is reasonably confident that the five conditions listed below are met.

1. There is a reasonable chance that research efforts will result in a commercially viable product or process.

A firm seeking investment opportunities must be reasonably certain that a proposed product or process innovation can be developed in a given time, at an affordable cost, and that there is a market capable of supporting a price that provides an adequate return on investment. The twin factors of time and cost are extremely important to a firm, especially during periods of economic instability. Projects that require large initial investment and take a long time to show a return usually do not compete well for corporate capital. Projects that stimulate further corporate investment as they begin to show promising returns are much more attractive; however, there are currently few such opportunities in the MPS area. In order to make a reasonable projection as to a project's possible rate of return on investment, a firm must have a clear view of the relevant market. When dealing with a new technology without a well-defined market, the firm's projections become more suspect, so that its investment in that technology would be at greater risk. The combined burden of developing new markets simultaneously with new technology may inhibit investment in MPS. It should be noted, however, that some MPS technologies (e.g., electrophoretic processing) will be directed toward well-defined Earth markets (e.g., pharmaceuticals). In these instances, the decision to invest in MPS technology may be preceded by standard market analyses.

2. The benefits of processing in space will be substantially greater than those of processing on the ground.

The MPS experimentation conducted to date indicates that many innovative uses of the space environment are possible. From a commercial perspective, however, the question is not what projects are technically possible, but rather which are economically viable. For example, it has been claimed that if semiconductor electronic crystals were grown in space, they would be purer, with fewer imperfections, and would therefore perform better. However, a recent study by the National Research Council has found that the quality of the preprocessed material is not the limiting consideration for most devices presently manufactured.[61] Therefore, though space-based manufacture of these devices may offer certain improvements, it is not clear that the benefits of the improvements outweigh the costs of producing them.

3. The market for the product will not be replaced by advances in Earth-based production.

It is possible that improvements in Earth-based technology may make certain processing tech-

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[61] The National Research Council, *Materials* Processing in *Space*, Washington, D. C., 1978, p. 5.

[62] Ibid., p. 38.

niques possible that previously could only be done in space. Evidence for this view is provided by recent advances in the manufacture of glass products through the use of acoustic levitation, and by the enlargement of latex polymers by means of new chemical tech niques.[63] To the extent that such improvements confer some of the advantages of space-based processing without the high costs of in-space production, there is less incentive to'invest resources in expensive space technology.

4. intellectual property rights in space technology must be assured.

Though NASA has given assurance that industry will retain the rights to patents and trade secrets developed while working with NASA, such assurances are in the form of policy and regulations, not law. The present law vests the ownership of intellectual property developed under contract with NASA in the Government, but allows the Administrator to waive such rights. NASA has been consistent in its policy of not claiming an interest in such rights, but the specter of patent and trade secret loss, either through a change in policy or as a result of a legal challenge by third parties, still remains.

There is current congressional interest in new patent legislation that would grant greater rights to private developers working under Government contract.[65] Present law, however, is more liberal with small business, universities, and nonprofit firms than with large contractors. The status of proprietary information and trade secrets is consistently more uncertain.

5. National commitment must be certain.

Industry's planning is hindered by the fact that all space research depends on a Federal funding commitment to NASA, but the level of that commitment remains uncertain. Decreases in NASA's appropriations will cause delays in the flight testing of space technology. Such delays are costly, and in some circumstances could mean, at the corporate level, the difference between a successful project and a failure (as measured by dollar-return). Should MPS technology appear to offer a commercially viable product, some type of long-term, in-orbit facility may be necessary to assure the continuing supply of specific quantities of the product. At present, NASA cannot provide credible assurance that such a facility will be provided.

Government Incentives for MPS Research

In chapter 5, NASA's MPS activities are described. What follows is a discussion of the programs NASA has initiated to enlist commercial support in moving MPS toward operational status. The ultimate goals of NASA's MPS program are to:66

- perform research to improve industrial technology or to develop new products;
- prepare research quantities of space products for comparison with Earth-based products; and
- encourage the production of commercially viable materials.

In hope of commercializing MPS, NASA has established three levels of working relationships with the private sector. On all three levels, the relationships are agreements between NASA and its partners to cooperate in a defined area. Each agrees to accomplish specific tasks and to provide its own funding. The grading of these relationships marks the degree of the signatories' commitments.

For companies interested in the application of microgravity technology, but not ready to commit themselves to a specific space flight experiment or venture, the ***Technical Exchange Agreement*** (TEA) has been developed. Under a TEA, NASA and a company agree to exchange technical information and to cooperated in the conduct and analysis of continuing ground-based research programs. In this agreement, a firm can familiarize itself, at minimal expense, with microgravity technology and its potential applicability to a product line. Under the TEA, the private company funds its own participation and

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[63] *Industry* Week, Mar. 3, 1980, p. 90.

[64] NAS Act 1958, see 305 (a); 42 USC 2457.

[65] Gerald J. Mossinghoff, "intellectual Property Right in Space Utilization, " address before the ALI-ABA Conference, "Doing Business in Space," Washington, D. C., Nov. 12-14, 1981.

[66] Robert A. Frosch, "NASA Guidelines Regarding Early Usage of Space for Industrial Purposes, " NASA Internal Document, June 25, 1979.

obtains direct access to and results from NASA's facilities and research; in return, NASA gains the support and expertise of the company's research capability.

In an ***Industrial Guest Investigators Agreement*** (IGIA), NASA and industry share sufficient mutual scientific interest that a company arranges for one of its scientists to collaborate (at company expense) with a NASA-sponsored principal investigator on a space flight MPS experiment. Once the parties agree to the IGI's contribution to the objectives of the experiment, he becomes a member of the investigating team, thus adding industrial expertise and insight to the experiment.

The ***joint Endeavor Agreement*** (JEA) is a cooperative arrangement in which a private sector offeror and NASA share common program objectives, program responsibilities, and financial risk. The objective of a JEA is to encourage early private sector investment in MPS by sharing in the cost and risk of initial space ventures and to determine the ability of MPS to meet needs of the marketplace. A JEA is a legal agreement between equal partners; it does not initiate procurement. Under a JEA, NASA and its partner exchange no funds. An offeror from the private sector selects an experiment and/or a technology demonstration in compliance with NASA's objectives for its MPS program, conducts the necessary ground investigation, and develops flight hardware at company expense.

As incentive for a JEA investment, NASA agrees to provide transportation on the shuttle, provided that the project meets certain basic criteria, such as technical merit, contribution to innovation, and acceptable business arrangements. As a further incentive, the participant is allowed to retain certain proprietary rights to the results, particularly the proprietary information that would yield a competitive edge in marketing products based on the MPS flight data. NASA agrees not to enter into a JEA with a second potential source to investigate a similar space-based process. NASA also receives sufficient flight data to evaluate the significance of the results, and can require as part of the JEA that any promising results be applied commercially on a timely basis; if in NASA's judgment the participant does not commercialize the results within a reasonable time, NASA is allowed to publish the research findings.

By establishing legal and managerial mechanisms by which the cost and risk of early commercial ventures can be shared, "constructive partnerships" have been formed between the Government and the private sector. A number of cooperative agreements are in various stages of discussion. Agreements now in force, and those that have been publicly disclosed are:hz

- A TEA was signed in 1981 with Deere& Co., to study the effects of microgravity on solidification of metals. More recently, TEAs have been signed with INCO and DuPont.
- An IGI was appointed in 1980 by TRW to study directional solidification.
- Signed in January 1980, the first JEA pairs NASA with McDonnell Douglas. The process to be investigated is continuous flow electrophoresis (CFE), in which materials in solution are separated by subjecting them to an electrical field as they flow continuously through a chamber. The CFE experiment, to be flown in the shuttle, is designed to demonstrate the applicability of the process to the production of marketable quantities of pharmaceutical products. Ortho Pharmaceutical Corp. has joined McDonnell Douglas as a partner in this MPS business venture.
- GTI Corp. signed the second NASA JEA in January 1982. Under this agreement, NASA will fly a multiple microexperiment flight package (MMFP) to be developed for GTI by a third party. The MMFP will be a furnace with multiple subenclosures designed to perform and control several separate experiments in solidification, GTI's role in this JEA is to serve as a broker between NASA and potential investors, customers, inventors, and hardware manufacturers.

How Business Sees NASA

Industry's respect for NASA's accomplishments and technical talent is high. However, doing business with NASA is complex, involving par-

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[67] R. L. Brown, and L. K. Zoner, "Avenues and Incentives for Commercial Use of a Low-G Environment, " MPS Projects Office, Marshall Space Flight Center, Alabama, undated.

ticular NASA policies and general Government policies. Uncertainty about NASA's level of funding, short- or long-term, makes for an unstable environment for private investment. To date, industry has not been assured that NASA will have enough funding to continue development of MPS systems beyond the early research stage. If unable to rely on NASA for continued basic development of new technology, industry sees no long-term future for MPS (whatever the temporary success of McDonnell Douglas and CT!).

Additionally, industry not involved in MPS generally finds NASA's JEAs to be in various ways unrealistic. Some industry observers read NASA as (in order to free itself to do little other than basic R&D) seeking partners who can do everything—marketing, financing, hardware development, etc NASA's agreement with GTI is a bold step toward meeting this objection. Through the guest investigator, technical exchange, and joint endeavor process, individual companies, concentrating on discrete tasks, can more easily enter the MPS field.

Businesses that have considered some commercial activity in space have also expressed concern over the potential loss of intellectual property rights (e.g., patent, trade secret, and industrial techniques). There are several reasons for this concern: 1) should such intellectual property become a matter of "Government record," competitors might be able to obtain this information through the Freedom of Information Act, 2) the 1958 NAS Act provision which states that NASA shall "provide for the widest practical and appropriate dissemination of information concerning its activities, " is at odds with the industry's desire to maintain the secrecy of R&D directed to potentially valuable products; and 3) section 305 of the NAS Act vests in the United States, subject to the discretion of the NASA Administrator, the right to any invention "made in the performance of any work under any contract" with NASA. Though NASA's Administrators have consistently waived the Government's rights under the act, industry's concerns remain.

'Possible New Institutional Frameworks

Though NASA is attempting to encourage private-sector interest in MPS through its TEAs, IGIs, and JEAs, a different institutional framework may eventually be needed, if the private sector is to be brought into MPS in a major way. To date, discussion has centered around three possible structures: an organization like COMSAT, a space industrialization corporation, and a possible consortium of industries. No consensus on this question has yet emerged.

The COMSAT Model. **In this scenario, a private corporation, established by legislative action, but financed through the issuance of capital stock, would** be given a monopoly **in the provision of processing facilities in** space. The Government would retain some degree of internal control over the organization by holding a number of positions on the board of directors, by regulating competition **in the procurement of equipment and services and by involvement in the ratemaking** process.

The purpose of such a corporation would be to supply a space platform with various facilities and services that users could rent. The extent of use by NASA, as a customer, and the degree of Government R&D performed on such a platform would be matters of policy to be decided at some point in the future.

A **structure like COMSAT'S has certain advantages. First of all, even with the substantial interest generated in** MPS over the past 2 years, private corporations might not wish individually to provide all the services needed to support separate processing facilities. Secondly, despite the obvious differences between communications and materials processing, one can envision an important similarity in the ways in which they might be conducted in space. A private concern might well operate a space platform with various facilities and services that users could rent. So described, such a platform could as well be used for materials processing as for communications. In neither case does the operator of the platform concern itself with the use to which its rented facilities are put. In both cases the operator might be expected to put some of these facilities to its own use.

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[68] OTA workshop, Materials **Processing in Space, May 1981.**

The biggest obstacle to the creation of a federally chartered structure is that the basic science on which MPS would be founded is insufficient for marketable quantities of products to appear in the near term. It is the view of ESA, for example, that at least 10 more years of basic science are needed before serious consideration of commercializing MPS can be given.[69] ESA, therefore, considers MPS a scientific rather than an applications program.

Two objections to the federally chartered structure have surfaced. One is that, at its founding, COMSAT was supported by significant expertise already existing in corporations and Government agencies. No such MPS expertise now exists. The other is that COMSAT entered an established and revenue-producing market, whereas a similar MPS corporation would be entering an unknown market. In any case, objections to the COMSAT model for MPS that are founded on various insufficiencies (whether of basic science, of relevant expertise, or of ready markets for products) argue for no more than a delay in the time when such a corporation might be chartered.

Although no organizations are now processing materials in space, to the extent that processes to be implemented in an MPS program are extensions of current terrestrial processes, relevant expertise exists in abundance. 'o Furthermore, to the extent that MPS products may improve the quality of similar terrestrial products by one or more orders of magnitude, marketability for some of them appears high.

The Space Industrialization Corporation (SIC)

Introduced primarily as a means to provoke public discussion, the Space Industrialization Act of 1979 (H. R. 2337) called for:[71]

> **Establishment of a Space Industrialization Corporation to provide a means for financing the development of new products, processes, and industries using the properties of the space environment.**

H.R. 2337 was introduced to address the problems of the private sector in developing space processing capabilities and to provide a thorough and orderly examination of **the** means to reduce the business venture risk of using **space for commercial purposes.**

If SIC were established, it would function essentially as an investment bank, providing capital through direct equity investments, loans, and loan guaranties. The problems most often cited by those opposing SIC in its present form are that such an organization is premature and that it may interfere with the activities of NASA.[72]

Some fear that given our limited knowledge of MPS science and engineering, SIC might encourage technically and economically unsound projects, which could have a negative impact on the evolution of space industrialization. They also argue that if companies are not required to put up their own money, they will take excessive risks and give projects inadequate management attention.

A different set of concerns regarding the SIC center around how this organization would affect NASA's continuing activities. NASA has been given a broad mandate to serve as a research and development center for U.S. space technology. SIC, as described above, would function primarily as an investment bank. Viewed in the abstract, these two entities would appear not to interfere mutually, but to be perfectly compatible. What many fear, however, is that, because space industrialization technology and its commercial applications are yet unproved, SIC could do little more than supply funds for basic R&D. If this were the case, then instead of complementing NASA, SIC would act as a competitor.

INDUSTRY CONSORTIUM

One way to encourage high-risk, expensive MPS research is to allow firms jointly to fund these activities. By allowing the sharing of key resources such as facilities, personnel and capital funds, the cost and the risk of space-based innovation would be reduced. A consortium of these firms-would also have considerable market strength because it could share the combined expertise of its

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[69] See ch. 7, p. 179.

[70] OTA Workshop, Material Processing in Space, May 1981.

[71] The Space Industrialization Act of 1979, Hearings on H.R. 2337, before the Subcommittee on Space Science and Applications of the Committee on Science and Technology, U.S. House of Representatives, 96th Cong., 1st sess.

[72] Ibid., testimony of Robert A. Frosch, p. 78.

members, which normally address differing customer communities or markets.

The structure of such a consortium would have to be carefully drawn so as not to be in violation of U.S. antitrust laws.[73] Simply stated, these laws are designed to prevent monopolistic market structures and/or collusion between competitors leading to price fixing and market or customer allocation. It is possible that a consortium as described above could violate both of these tenets.

Because of the time and expense involved in most antitrust litigation, firms tend to be cautious when dealing with their competitors. it is unlikely that in the absence of a well-articulated Government policy condoning such conduct that potentially interested firms would form such a consortium. In 1980, however, the Justice Department issued guidelines "clarifying" its position on cooperative ventures: as long as these ventures are open to all prospective participants and the research they undertake is fundamental and long range, the Department will probably not object.[74] More than a score of the largest U.S. computer manufacturers and their semiconductor suppliers are forming just such a research consortium under the Semiconductor industries Association.[75]

International Competition in MPS

The European states and the Japanese agree that MPS has great long-term promise, and they support extensive basic research preparatory to possible commercial ventures. The ESA-funded Spacelab designed to be flown on the shuttle will provide facilities for such MPS experiments.

The Germans, who are the prime contractors on Spacelab, are particularly interested in MPS and plan an extensive combination of scientific and industrial projects, with some hope of significant near-term results.[76] The French have fewer near-term activities, but are hoping for extensive future use of the Ariane launcher to orbit processing facilities for scientific and industrial uses.[77]

The Japanese program is similar to that of the Germans.[78] The Japanese plan to conduct MPS studies aboard Spacelab, and are using an extensive sounding rocket program to gain preliminary knowledge. The Japanese expect that in the long term at least some MPS work will result in the development of marketable products.

Far more extensive than any MPS efforts in the West, the Soviet MPS program has, so far as can be ascertained, been geared to manufacturing process research, much of which extends to studies of terrestrial production techniques.[79] Because there is no private sector to participate in the Soviet space program, and perforce, no concern for commercialization, any inference from Soviet experience in MPS to Western attempts to commercialize would be risky. Soviet MPS experiments, which have been conducted aboard the Salyut 6 manned orbital lab, appear likely to continue at a high rate during the next few years.

Perhaps the best lesson to be drawn from this cursory review of the activities of other nations is that the United States has a variety of paths it may follow in the development of MPS technology. If it is to establish and sustain a successful, long-term MPS program, basic research must surely go forward. The speed of this research and the extent of private sector involvement are matters of policy to be decided in the context of our overall space goals.

A key question for the near future is the extent of international cooperation in MPS basic research. U.S.-European collaboration on Spacelab makes it possible to conduct joint efforts at the basic science level, provided competitive strains are not too great.

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[73] U.S s. Department of justice, Antitrust Guide Concerning Research Joint Ventures, November 1980.

[74] 1bid.

[75] Tom Alexander, "The Right Remedy for R&D Lag," Fortune, Jan. 25, 1982.

[76] See ch. 7, pp. 192-193.

[77] See ch. 7, pp. 190-191.

[78] See ch. 7, pp. 201-202.

[79] See ch. 7, p. 207.

SPACE TRANSPORTATION

Issue 7: What are the Major Barriers to Commercialization of Space Transportation Facilities and Services?

Though the shuttle opens the door to relatively inexpensive access to space, it makes the problem of transferring the U.S. civilian space transportation capability to the private sector more complex. Because the shuttle is new, its track record is insufficient to allow corporations to assess its long-term expenses and risks. Full commercialization of expendable launch vehicles (ELVS), however, is possible now. But whether a private launch service using ELVS could offer a price competitive with the technologically superior shuttle or the ESA-subsidized Ariane remains an open question. Therefore, the near-term prospects for commercializing U.S. space transportation are unclear, and the long-term prospects ride with the shuttle. In any case, the single major impediment to commercialization of U.S. launch systems is the absence of a comprehensive Government policy that favors and encourages the participation of the private sector.

The Background

In the United States the Federal Government has heretofore provided launch vehicles and launch services for all users. While DOD generally launches its own spacecraft, NASA has provided these services for its own missions and, on a reimbursable basis, for other U.S. Government users, foreign governments, and private entities. (NASA's policy on reimbursement seeks, in general, to recover incremental, out-of-pocket costs only, not capital already invested.) Of the roughly 20 to 30 U.S. launches per year over the last 10 years, about one-third were DOD's, one-third were NASA's own spacecraft, and the remaining third were for other United States or foreign government users and private entities. NASA's mission model[80] for the space transportation system (STS) for the next 10 years or so shows about the same ratio. A recent study by the American Institute of Aeronautics and Astronautics (AIAA), however, has projected a significant additional need for total launches, primarily for commercial communications satellites.[81]

Until 1981, all U.S. experience had been with ELVS. Until recently, civilian ELVS were to be phased out by the mid-1980s, and the sole U.S. launch capability was to be the NASA STS, represented primarily by the shuttle and its associated upper stage components. However, delays and uncertainties in the shuttle program have caused NASA to reexamine this policy. Proponents of retaining ELVS argue that the number of launches that will be needed will exceed the capacity of the shuttle, leaving the United States without sufficient launch capacity if ELVS are phased out.

Private industry has not generally marketed launch hardware or services directly to customers. ELVS are sold to NASA, which then charges the customer. Industry has, of course, built the launch vehicles under Government contract and to a degree, lesser (for NASA) or greater (for DOD), provided contracted-for launch services at Government launch facilities. However, NASA has remained responsible for providing launch facilities and support services to all users. Already, NASA is facing its first competition. Arianespace, a private French corporation with substantial Government ownership, has begun selling launches after a successful development program. Certain private corporations, such as Space Services, Inc., of the United States, hope to offer launch vehicles and services within a few years. An investment banking firm, William Sword, Inc., has offered to fund a fifth shuttle orbiter in return for exclusive rights to market commercial payloads. Already, small military rockets and satellite kick stages have been commercialized, and one of the shuttle upper stages, the SSUS-D, is being

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[80] **"Final Flight Manifest for Space Shuttle," Aerospace** *Daily,* **Dec. 18, 1981, pp. 253-257.**

El American Institute of Aeronautics and Astronautics, projection of non-Federal Demand for Space Transportation Services Through 2000, Jan. 19, 1981,

[82] *Aviation Week* and *Space Technology,* "Firm Sets Down-Payment for Buy of Space Shuttle," Jan. 18, 1982.

sold by the manufacturer (McDonnell Douglas) directly to the end user rather than to NASA.

Military and Civilian Use of the Shuttle

DOD is the only other U.S. launch agency, handling many of its own launches. How will DOD share the shuttle with civilian users? DOD has the right to preempt civilian flights in case of need. How will that right and its other special requirements affect hardware and launch costs? Generally speaking, OTA has not found any of these concerns to be major impediments to civilian use of the shuttle—provided that the projected launch schedule of one flight every 2 or 3 weeks is attained. Once this planned flexibility of the shuttle system has been realized, a DOD preemption of a shuttle flight would probably have little adverse affect on civilian needs, most of which are not time-sensitive over periods of a few weeks. For now, it is essential that at least one line of ELVS be retained, both to provide additional capacity and to back-up the shuttle, In addition, it may be prudent to continue development of expendable launch vehicle technology for certain payloads (see ch. 10).

The questions of DOD's share and requirements in STS decisions are mostly settled, but retain historical interest. The shuttle was planned to be a “national” program; i.e., it would serve all customary U.S. launch needs for payloads that were in the shuttle range. Specifically, this implied that NASA and DOD would need to define a common, acceptable payload bay size, operating characteristics, and compatible subsystems. The major premise was that such a substantial investment in a new technological capability could not reasonably be made unless it could serve the broadest set of national needs. The initial concept included the possibility that DOD would assume some degree of responsibility to fund development of the shuttle. This was subsequently modified in view of DOD's rather substantial budgets already in existence for other weapons systems and space developments; the shuttle was included in NASA's budget, though, of course, support for the program rested on congressional recognition of its military uses. It was agreed that DOD's direct share of the program development costs would be limited to two items: a west coast launch site for the shuttle, and development of an interim upper stage (I US) for boosting shuttle payloads into higher orbits.

The resulting agreement gave NASA the responsibility to purchase and operate the STS for everyone. DOD would have missions solely for its use, but NASA would own and operate the launch capability equitably for all users. Certain DOD requirements did drive initial shuttle costs higher than the estimates of NASA's original proposal, but most requirements also resulted in greater, if more costly, capabilities. As DOD has generated additional requirements (for its own mission control center for example), the Department has itself bought these capabilities. This division of responsibility is expected to hold henceforth. NASA's pricing policy for the shuttle remains problematic, especially in view of the 73 percent increase in the projected average cost of a standard mission (from $16.1 million in June 1976 to $27.9 million as of September 1980). According to a recent General Accounting Office (GAO) study, NASA is “locked into a pricing policy that encourages space transportation system use at NASA's expense and at the expense of the space science, applications, and aeronautics programs. GAO believes DOD and other government agencies should bear a greater share of the shuttle's early years operations costs . . .“13[3]

The division of the U.S. space program into civilian and military components has been a valuable tool of foreign policy. DOD's involvement with and ultimate use of the shuttle have raised the issue of the possible militarization of the entire U.S. space program, a possibility that is unsettling to other nations, especially the third world and the Soviet Union. The United States has assured other nations that the programs will remain separate, but their concerns are likely to remain until the passage of time and experience with the shuttle show whether or not the civilian program remains unmilitarized.

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[83] *General* Accounting Office, **“NASA Must Reconsider Operations Pricing Policy to Components for Cost Growth of the Space Transportation Systems, ” Feb. 23, 1982, pp. ii-iii.**

Foreign Competition in Space Transportation

Currently, the United States has no policy regarding foreign competition in space transportation. Though the Soviet Union has had a reliable launch capability for 25 years and has launched satellites for several other countries, it does not sell launches. However, commercial competition from the ESA'S Ariane ELV is now a reality. The Ariane (which is approximately twice the size of the U.S. Delta) has recently completed a successful series of test flights, and the Europeans are now selling space on future launches. Already several U.S. telecommunications companies have switched from NASA launches to Ariane, and more such decisions can be expected because fewer shuttle opportunities are available and U.S. ELVS have become more expensive. The Ariane's attractiveness is enhanced by the creation of Arianespace to market the Ariane and provide launch services. Arianespace, in conjunction with European banks, is offering customers below-market financing and other financial incentives that compare favorably to present U.S. pricing procedures. Arianespace plans initially for five to six launches per year, rising to 10 per year in the mid-l 980s.

The Japanese space agency, NASDA, is currently building and operating modified Delta launchers, designated N-1 and N-11, built under license from McDonnell Douglas. At present the Japanese are prohibited from selling launch services to third parties without U.S. permission; development of a completely Japanese launcher is planned but is not likely to be completed before the end of the decade.

Regulatory Needs

There is now no clarity with regard to regulation of private launches from the United States, largely because there is no single Federal authority for overseeing private space activities from launch to flight termination. The absence of such authority creates a number of problems. First, although certain agencies (FAA, FCC) exercise limited authority over private rocket launches, the absence of clear Government policy and procedures creates confusion as to who has the authority to authorize a private launch. Second, existing Federal launch centers, because of launch conflicts and space limitations, may not be sufficient to meet the future demands of private spaceflight operations. The proper role of Government in the construction, operation, and regulation of new commercial launch sites has yet to be addressed. Indeed, the issue is so recent that the Federal agencies that have interest or jurisdiction have just begun to address it. Finally, it may be prudent to devise some type of mandatory insurance scheme to indemnify the Government and protect the general populace from the possibility of accidents resulting from private launches.

Once a comprehensive regulatory scheme is adopted and a clear Government policy articulated, the institutional risks inherent in operating a private launch system will be diminished, and greater private sector participation may occur.

Prospects for Commercialization

Though the complete transfer of shuttle operations to the private sector does not seem likely in the near future, there is no reason why the private sector could not eventually supply this service. As technical experience is gained, the reliability of shuttle systems proved, and information is obtained concerning the real costs of operating the shuttle, the commercial potential of this system will also begin to be understood. If the transfer of the shuttle to the private sector is determined to be in the national interest, firm Government policies to this effect must be articulated and, where necessary, supported by financial incentives.

No private sector firm has yet expressed interest in operating the entire shuttle system (i.e., orbiters and related launch hardware, and ground support and maintenance facilities), but there has been some interest in the operation or ownership of discrete parts of the launch service. Currently there are three areas where private sector involvement may become important:

- ***Tracking, telemetry and control.–In*** 1979 COMSAT established the first commercial launch control facility that offered services previously only provided by NASA. As space activities become more common, opportunities for the private sector to provide these services will increase.

- ***Shuttle refurbishment.–currently,*** NASA contracts with more than 25 private firms to refurbish the orbiter between flights. NASA has **recently decided to find one firm to act as a manager** for the entire process.
- ***Orbiter ownership.–As*** mentioned above, a U.S. investment banking firm announced its interest in purchasing the fifth orbiter, with the provision that NASA would continue to operate the vehicle but that its payload capacity would be marketed by the private owner. Should this venture prove to be successful, the likelihood that other orbiters will be privately owned will be greatly increased.

Full commercialization of ELVS, however, is possible now. There are few if any unknowns surrounding their operation. The market for launches is steadily growing: though it is not large enough to support all the expendable lines (Titans, Atlas-Centaurs, Deltas, etc.), it could certainly support one of them. Because of various uncertainties, the aerospace companies have not shown much interest in dealing directly with any group backing private launch services. A possibility here would be the mediation of a third-party broker, A further possibility might be the formation of a Government-chartered private corporation to provide launch services, leasing facilities at Kennedy Space Center. Rapid commercialization of U.S. ELVS would provide immediate advantages: competition for the Ariane, added incentive to NASA to bring the costs of shuttle operations down, and a backup system for the shuttle should it meet unexpected problems.

Chapter 4

DEVELOPMENT AND CHARACTERISTICS OF THE U.S. SPACE PROGRAM

Contents

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DEVELOPMENT AND CHARACTERISTICS OF THE U.S. SPACE PROGRAM

INTRODUCTION

Nearly a quarter century after Explorer I and the U.S. entry into the space age, the space shuttle now presents the Nation with new and expanded opportunities for space operations. In the coming months and years, we will learn to operate and use the new capabilities of this system. It is indeed ironic that, at this time of brave new beginnings, the Nation again faces important questions about the future of the civilian space program.

At the inception of the space program, the United States perceived Soviet initiatives in space as political, military, and technological threats. Having seen space as a field in which to compete, the United States directed its space program toward the primary objective of exceeding Soviet achievements. With the passage of time, and the great success of Apollo, Soviet competition no longer challenges the United States politically. But as the Soviet challenge has vanished, so has the motivation of beating the competition. Now the United States is faced with the more sophisticated challenge of devising a balanced policy framework—a framework that will enable the United States to identify new objectives and stimulate the Nation to achieve them. Lacking such a perspective, the Nation has, instead, begun to evaluate space more pragmatically. This evaluation suggests that "activities will be pursued in space when it appears that U.S. national objectives can most efficiently be met through space activities."[1] It contrasts with the aggressive acceptance of the "role of the United States as a leader in aeronautical and space science and technology and in the application thereof . . . ," as prescribed in the National Aeronautics and Space (NAS) Act of 1958.[2] The act itself, however, established no spe-

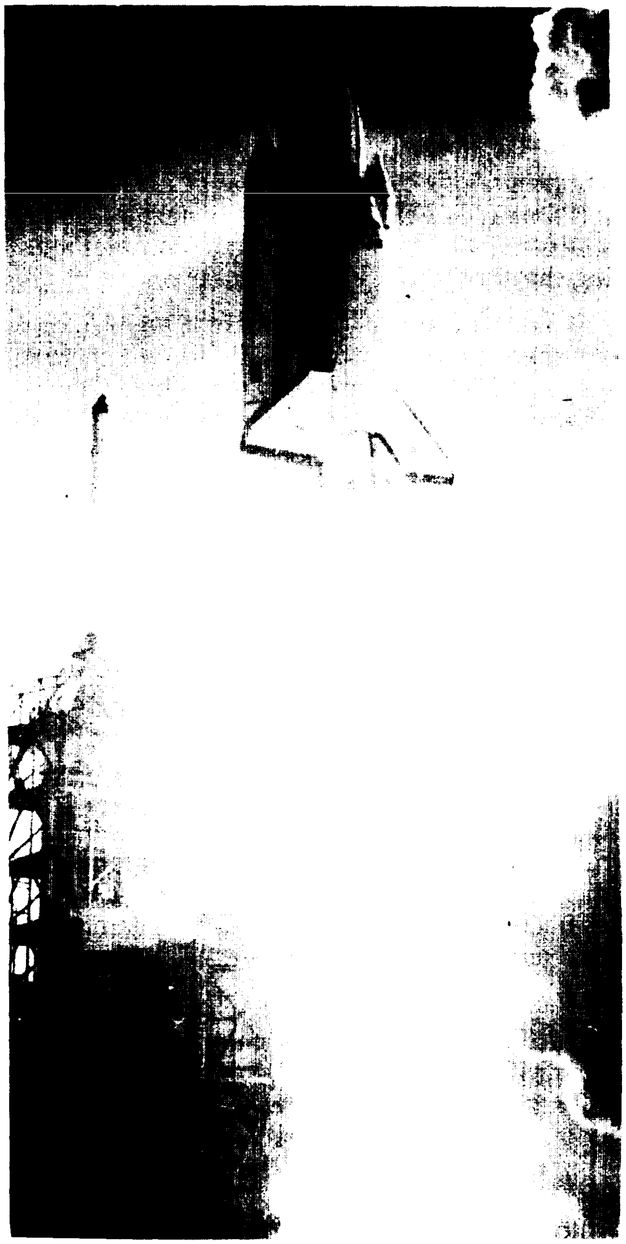

Photo credit: *National Aeronautics and Space Administration*

The dawn of a new age in space flight, Space shuttle *Columbia* blasts off Pad 39a, April 12, 1981, with astronauts John Young and Bob Crippen aboard

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[1] "White House Fact Sheet on U.S. Civil Space Policy," Oct. 11, 1978.

[2] *National Aeronautics and Space Act of 1958,* as amended, and related legislation. Prepared at the request of Hon. Howard W. Cannon, Chairman Committee on Commerce, Science and Transportation, U.S. Senate, December 1978.

cific manned or unmanned missions, outlined no priorities, nor specified a funding level at which the program was to be carried out. Instead, the commitment to Apollo set the civilian space program on the expansionary course that provides the baseline for current comparisons. Likewise, this commitment generated the momentum that is largely responsible for sustaining the program today. But now, with current budgetary stringency, commitments to civilian projects are few and uncertain, though the military and national security programs continue to grow. Consequently, it is timely, as we embark on the next decade of space activity, to scrutinize and to consider revising the framework of U.S. space policy.

Basic to any overall assessment of the U.S. civilian space program, particularly one which seeks to assist Congress in setting public policy for charting the Nation's future in space, is an interpretive, retrospective review of our current posture in space, how the United States has proceeded to develop its current program and the capabilities on which the program is based, the role of various external factors such as international competition, the processes that have shaped its current posture, and other relevant forces and environmental factors that led to, or provided the foundation for, the current situation facing the United States in space. This chapter presents the results of such a retrospective review applied to the civilian space program of the United States, emphasizing those aspects that are relevant to space applications. It is intended to highlight issues and lessons learned, as well as characteristics of previous decisions regarding the program that may have applicability to current and future developments.

The civilian space program of the United States has grown from its early beginnings as part of operations in connection with the International Geophysical Year, to the great successes of Apollo, Viking, and Voyager, in the short span of one generation—a little over 20 years. Thus, history and current practice are woven together in a tapestry, with many threads still in place that bind past and present: still present are many individuals in the National Aeronautics and Space Administration (NASA) who have been with the agency since its beginning, contractors that have played a continuing role over this period, and institutional relations that are relatively unchanged since the earliest days of the agency. There are both strengths and weaknesses in such a situation. To the extent that it is desirable to prevent making the same mistakes as one's predecessors, such continuity and institutional memory is important. To the extent that it serves to limit the Nation's ability to take a fresh look at the program, how it functions and how it should respond to a changing external environment, the strong links to the past may inhibit the agency from becoming a dynamic vehicle of change and the source of new initiatives involving the use of space systems.

In addition, the relatively short span between establishment of NASA and this assessment makes it difficult to separate the objective views of participants from a tendency to defend their own decisions and roles. Because of this problem, this history and analysis is primarily based on specific events, documented roles and decisions, observed consequences, and supporting statements.

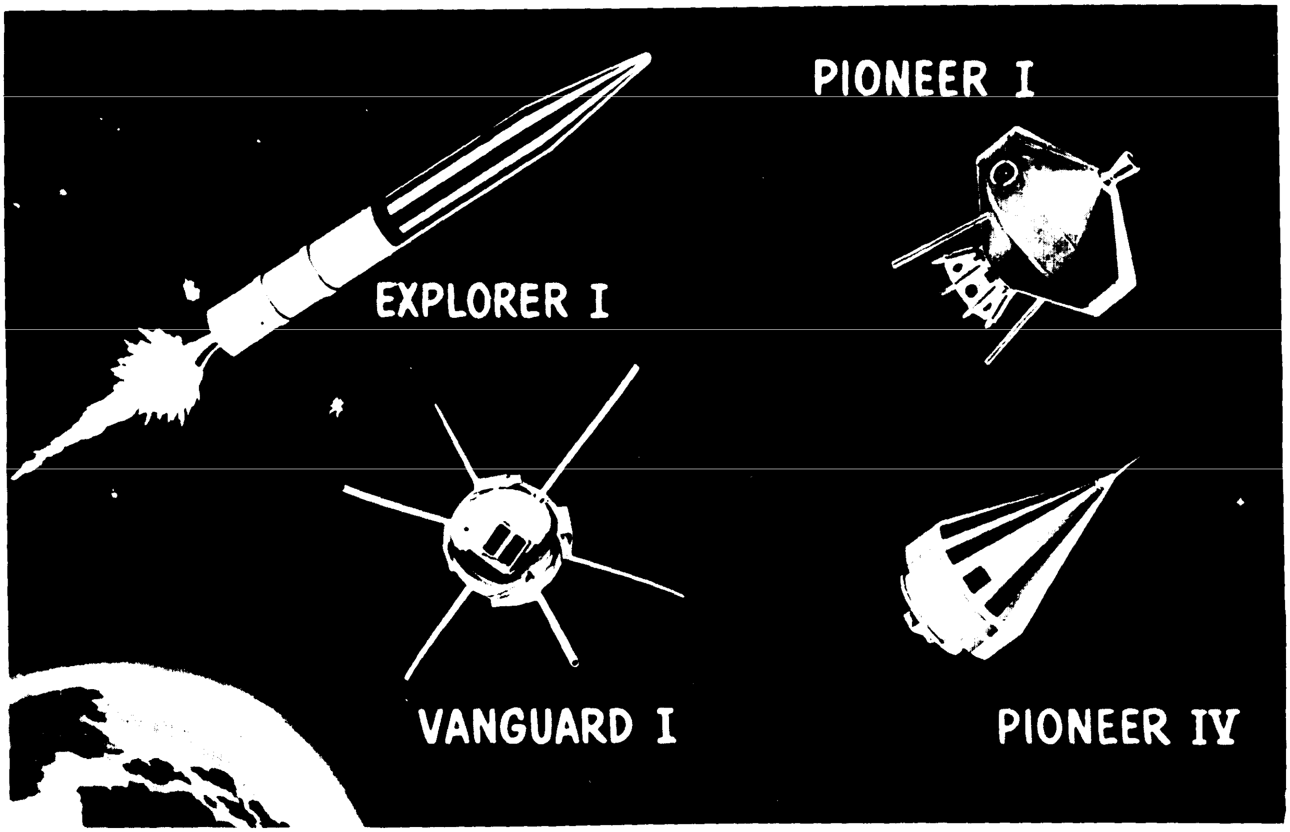
Although the civilian space program is a relatively recent activity of the U.S. Government, it is unique among Government programs in its high public visibility. It has been the subject of many historical evaluations and popular histories. NASA from its very beginning devoted attention to the development of an official chronology, and in the past there was an annual report of space activities submitted to Congress, summarizing the full scope of the U.S. civilian space program. Together, these resources report the history and evolution of the civilian space program in great detail, and there will be no effort in this report to duplicate such materials. The specific programs or decisions discussed in the sections that follow have been selected to illustrate an issue or to support a conclusion so the material selected is not a comprehensive or exhaustive lising of milestones or significant events. In keeping with this assessment's focus on civilian activities, the present chapter does not discuss the extensive military space program except as it illustrates a policy issue of significance for the civilian space program. Its focus is primarily on NASA's activities, though it includes some discussion of programs of the National Oceanic and Atmospheric Administration (NOAA).

EARLY DEVELOPMENT

The early development of the U.S. space effort was primarily a specialist's concern; that is, the scientific research objectives associated with the prospect of access to the upper atmosphere and eventually to an Earth-orbiting platform were the province of a relatively small community of scientists and engineers. This community included a few universities, not-for-profit institutions, and several defense laboratories. There was associated with this research-oriented community a larger engineering-oriented group that was developing propulsion systems, radio and inertial guidance systems, and control systems for ballistic missiles. **This second group provided much of the basic launch vehicle technology** for the civilian program. Before Sputnik in 1957, these groups pursued their objectives in relative obscurity.

In the wake of Sputnik, however, the public demand for a U.S. response galvanized Congress and the executive branch to act. Seeking to revitalize technological and scientific development across-the-board, they instituted programs to develop better science and engineering education, to increase Federal support for science, to attract greater numbers of young people to technical careers, and to improve military systems.

One of the first measures taken was to appoint a full-time Science Adviser to the President, Dr. James Killian, and to establish the President's Science **Advisory Committee** (PSAC), a **group** of 18 respected senior scientists and engineers. They were asked to review and comment on the measures needed to carry out the peacetime mobiliza-



Spacecraft used **in the early stages of space exploration**

tion of skills in science and technology called for by the President. Clearly, the major topics of review were: 1) the U.S. response to Soviet space achievements and 2) the national security programs needed to counter Soviet military developments, particularly their ability to launch ballistic missiles and to detonate hydrogen bombs.

One of the first tasks at hand was to explain to the public the significance of the Soviet and U.S. entry into space. Many people could not understand how orbital flight around the Earth was possible, and they found its realization threatening. Thus, in its first public report, PSAC found it necessary, in 1958, first, to expound Newton's laws of motion to explain "why satellites stay up," and second to assure the public that the Soviet space achievements did not signal a serious, imminent threat to U.S. national security.[3] In this same report, PSAC outlined the future evolution of the space program, including (under the categories of near-, mid-, and long-term possibilities) the full range of missions that the United States, with time, could adopt as the national space program. The remarkable feature of the report was the very complete characterization of future applications, including manned planetary exploration and a lunar base, both listed as long-term goals, and both still possible as targets for future space activity.

{n those early days of civilian space activity, the principal objectives were to acquire new knowledge, performing specific functions that were enhanced or made uniquely possible by utilizing space platforms, and to strengthen national prestige and self-confidence, badly shaken by a succession of Soviet "firsts" in space. These objectives appeared prominently in the NAS Act, which was prompted by Sputnik and very quickly drafted and signed into law in July 1958.

As is clear from chapter 5, the essential character of the civilian space program has not changed significantly in the succeeding years: we still seek new knowledge about the Earth, the Moon, the Sun, the planets, and the more distant objects in space; we remain active in exploiting applications that make use of the unique vantage point or the unique environment (low gravity, high vacuum) of space; we still attend to exploration and technological "muscleflexing" in programs such as the space shuttle. Perhaps one of the most remarkable aspects of the way the space program has developed is the fact that the opportunities and areas of activity in the space program have not changed appreciably over a quarter century. The developments in space applications, the mission opportunities in science, and the manned space exploration program have largely followed the scenario laid out by the early advisers and space proponents—if anything, they have failed to equal the imagination and vision of these early projections. This suggests that we have not yet penetrated beyond the initial learning phase of space activity to a more mature treatment of and familiarity with space systems, and how they can best serve us.

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[3] *Introduction to Outer Space,* **report of the President's Science Advisory Committee, 1958.**

MAJOR CHARACTERISTICS OF THE SPACE PROGRAM

In order to build a foundation for the analysis of later chapters, this section will highlight a number of important characteristics of the U.S. civilian space program which have been instrumental in setting the stage for current issues.

Open and Public Nature of the Program

As the NAS Act separated civilian and military space activities, the civilian space program was open to public scrutiny from its inception. This characteristic of the program has helped to shape and, in a sense, to constrain the U.S. civilian program. As the public has become more knowledgeable about space capabilities and costs, the objectives of NASA's program have required more detailed justification, more planning, and even some marketing in order to build sufficient public understanding and acceptance. The growing complexity of technology and missions in space applications and science requires more sophisticated public understanding than did some of the earlier programs, As a result, NASA's task of justifying its activities to the public has become more difficult.

Contrasted with the public acceptance and support that NASA requires is the more restricted nature of the decision process for the space program in the military and intelligence arenas. Here, the very large majority of the program is space applications, that is, activities which assist in performing a specific mission or missions and which are therefore amenable to cost-benefit analysis. It is quite often the case that any one of several alternatives may achieve the objectives of a given mission, and that tradeoffs may determine the optimal allocation of resources from among the various alternatives available, For the most part, this decision process takes place in the closed world of the Department of Defense (DOD) or the Central Intelligence Agency. There is, consequently, no need to sell the program to the public, nor do elected public officials participate in the selection, the configuration, or the operation of missions. The important element in this process is the mechanism for generating requirements. The requirements provide a target toward which the technical community can work and by which the proposed system may be evaluated. **It** would be difficult to devise an analogue to this mechanism suitable for use in the civilian program because in the early stages of R&D, civilian users and, perforce, their requirements cannot be identified.

Use of Industry and University Support

From its very beginning, the space program has been a high-technology endeavor, and the average citizen has not easily understood its operative concepts. Early failures in both launch vehicles and satellites dramatized the problems associated with space operations and taught invaluable lessons to those who were actively participating in their development. Practices and techniques that were adequate for most terrestrial systems had to be modified and adapted to the demanding requirements imposed by the space environment. As a result, highly skilled industrial teams were formed. These teams learned to apply specialized manufacturing and environmental specifications and found ways in which they could be satisfied. They also developed a wide variety of associated techniques that could be perfected only through actual space missions. Such specialized knowledge and specialized capability in industry and universities represent a national resource that, if lost, could not be easily duplicated.

An important characteristic of the U.S. program in this regard has been the diversity of industrial, university, and Government resources that were drawn into active participation in all aspects of the program. Through this diversity of resources, there has been enough competition so that new ideas have had an opportunity to surface, space expertise has been acquired by many technical teams, and the entire program has been strengthened. Furthermore, significant diversity has always characterized intragovernment space activities. NASA's predecessor and major constituent element, the National Advisory Committee on Aeronautics (NACA), developed a major field laboratory structure (Langiey, Ames, and Lewis Research Centers), and it promoted valuable cross-fertilization through good working relations with its principal customers—DOD and the commercial aeronautical industry. When space activities began, and the level of effort was substantially raised, in accordance with our commitment to the success of Apollo, NASA elaborated NACA'S pattern: **it** created new government research centers, each playing a major role in program management, and each having unique facilities and a modest in-house research and technology development capability. NASA also enlisted the support of its counterparts in DOD, particularly with respect to launch vehicles (Thor, Atlas, Agena).

With a few notable exceptions, manufacturing and detailed system development were the province of industry, while university teams designed the instruments and experiments, formulated the overall science objectives, and constituted the user community for the space science program. For the most part, the relationships among these contributors have been beneficial and positive. From time to time, however, some concerns have surfaced. For example, the university experimenters complain about the privileged position of their competitors inside the NASA research centers, or NASA headquarters claims it lacks adequate control over the centers. An abiding concern of industry is that they will lose a significant business base from a combination of NASA's shrinking budgets and its desire to maintain an in-house establishment.

Overall, the United States continues to call on and use capabilities that were created as part of the major expansion during the Apollo program. However, shrinking NASA budgets, particularly when inflation is taken into account, have gradually eroded the contractor base supporting the civilian space program. Many contractors now prefer to work on DOD's space program. New civilian activity has slowed overall, particularly in some of the advanced scientific areas. Similarly, universities made significant commitments to space in the early expansionist days, and many specialized university space institutes or laboratories were established. Several factors threaten the ability of universities to continue their support of the space program. These factors include: increasing time intervals between successive launches; lack of funds to support continued data collection and processing of data from satellites after their initial period of operation; reduced funding for exploitation of data already gathered; and increasing complexity and leadtimes between initiation of an experiment and the actual flight opportunity. The support for the space program from universities and industry has enabled the United States to succeed in increasingly advanced and more challenging missions. This base of suport will be the key to the successful performance of commitments yet to be made. Clearly, the vigor of space-related programs in industry and universities is an appropriate subject for periodic evaluation.

Public Understanding

The community most immediately affected by the awesome character of launching artificial satellites were those who operated, constructed, and designed the various interdependent systems. The inception of manned flight brought the wonder of space exploration home to us all. For now our space program had become not only a scientific investigation of a new medium, but a human adventure into the unknown. As the first astronauts were selected, communications media hastened to canonize them as national heroes. Through extensive publicity, particularly live television coverage, people throughout the world followed the early manned flights with great interest. Familiarity with the astronauts, their space vehicles, and the new jargon of the space age led to some understanding of the relevant concepts: weightlessness (or "microgravity"), how satellites and launch vehicles operate, the difference between synchronous and low-altitude orbits, the concept of satellite communciations relay, and Earth observations from space for weather or other purposes, all became topics of casual conversation.

In addition, even rather esoteric subjects of scientific investigation, such as the structure of the Van Allen belts around the Earth, the composition and characteristics of the Moon, and the nature of the planets in our solar system, became matters of general interest. The space program, which began as the province of specialists, generated ever more publicity and discussion, so that the general public was eager to learn of, and participate vicariously in, the planning and flight of new missions.

Yet, even as the public came to understand the first steps into space, succeeding missions and systems became more enterprising: simple instruments were being supplemented by complex devices and systems, plans were made to investigate new objects, and the first surveys of these objects were followed by detailed and highly specialized analyses. In Earth-orbital applications, naive signal propagation and tracking devices evolved into sophisticated relay stations with multiple channel capacity and multiple spot beam retransmission capability; simple cameras and optical scanning devices were complemented by multispectral scanners and infrared or microwave imagers; and the tracking systems were supplemented by laser trackers of high spatial and range precision. The experiments to be performed by the next generation of space missions are even more complex.

Thus, the open and public nature of the civilian space program, coupled with its high technology content, presents a special challenge to policymakers and the leadership in the civilian space community, if there is to be some continued development of public understanding of space missions, program objectives, and the possible returns to be expected.

International Cooperation

It is impossible to discuss the overall U.S. space program without mentioning its international component. From its very beginning, the civilian space program has had an international character. International cooperation in science led to the first satellite launches as part of the multinational International Geophysical Year. The 1958 NAS Act explicitly recognized the objective of fostering international cooperation, and it charged NASA with integrating this objective into the overall program. Yet the consideration which dominated space policy in the early years was competition with the Soviet Union, and policy decisions during this period tended to protect U.S. interests against possible foreign preemption. Our treatment of international cooperation has also varied considerably, depending on the type of activity—space science, applications, or manned flight.

The approach taken to science has favored data exchange, large-scale cooperative experiments where multiple measurements at geographically dispersed locations are involved, and to a very limited extent, foreign experiments on U.S. satellites or use of data acquired by the United States (such as lunar samples). In general, the United States has regarded cooperative efforts in science as less problematic than those in other areas, although it has been assumed that the United States would participate in each area of space science with sufficient vigor so that we would remain in the forefront of current research and would not abandon any area to foreign competition.

In applications, the most notable activity has been the commitment to a single international communications satellite system, INTELSAT, and the creation of a chosen private entity, COMSAT, to represent the United States and, initially, to be technical manager for the system. In this area of commercial interest, many nations had to cooperate if links among the various communications systems were to be established. To this end, the creation of a new international institution seemed the most feasible means. On the other hand, introduction of Earth remote sensing through the experimental Landsat system has not yet required extensive international cooperation, so that no international institution to collect data has been created.[4] Of course, there has been extensive international dialog regarding Earth observations, and the sale both of the received data and of ground stations for direct reception of Landsat output are proceeding apace. Thus the Landsat program has not been without substantial international participation or commercial interest. It has been customary for Government to supply meteorological data as a public service, and this practice was continued with weather satellites. As in the case of terrestrial weather observations, free and open exchange of data has been the rule, where the United States makes ground stations available for receipt of U.S. meteorological data. Cooperation has grown in this area, particularly as part of a series of large-scale atmospheric ocean observation programs that gave other nations greater experience and an incentive to create their own meteorological capability at geosynchronous orbit. Navigational aid, also largely a Government service, was originally used to support military (submarine and surface ship) operations, but was later opened to civilian and international users merely by their purchase of the appropriate receiver. A more advanced system of position location is under development; it too will be available to civilian and international users.

Manned space flight, by its nature a very costly aspect of the space program, has been carried out only by the two space superpowers, the United States and the U.S.S.R. With the exception of lunar exploration, the U.S.S.R. has pioneered this area and has flown international

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[4] *Remote Sensing of Earth Resources,* **Panel on Science and Technology Thirteenth Meeting, proceedings before the Committee on Science and Aeronautics, House of Representatives, 92d** Cong., **2d** sess.; **Jan. 25, 26, 27, 1972; No. 13, Washington,** D.C.

crews with members from Socialist bloc countries. The U.S. program is moving toward international participation in manned flight with the advent of shuttle operations and a manned laboratory payload (Spacelab) supplied by a European consortium. Indeed, the shuttle system is an international cooperative venture, and the shuttle itself may very well be flown by multinational crews. In early manned operations, including Apollo, the need for close contact and global monitoring of flight crews and their capsules required tracking, communications stations, and recovery units around the world. These were part of a large-scale cooperative international framework established by NASA (and DOD) that supported the manned flight program and many unmanned operations as well.

More recently, other nations have designed and begun to test space systems that will compete directly with U.S. projects in communications, remote sensing, and transportation (ch. 7). Thus, cooperation and competition are both present in the international aspects of the civilian space program. As a result, there is a certain flexibility in U.S. space policy, ensuring that analysis and debate will continue.

MAJOR MILESTONES IN SPACE

The following milestones have been selected to illustrate the major issues and characteristics of the civilian space program of the United States and to lay a foundation for a retrospective assessment of our current posture in space.

The International Geophysical Year (IGY)

U.S. participation in the IGY program provided the explicit rationale for entry into civilian space activities. It was fundamental to this participation that the experiments would be open and the results published, consistent with the traditions of scientific research. There would be international discussions and exchange of results, and the knowledge gained would become part of the global scientific literature. in this work, therefore, were laid the foundations for an open and public civilian program with a fundamental objective: expansion of human knowledge. This contrasts with the military and intelligence space objectives —support of the national security of the United States–and the high degree of secrecy associated with most of their activities.

The search for knowledge is still an important objective of the U.S. space program and can serve to link people of diverse cultural and political backgrounds. It involves its own form of competition, but also enables nations to cooperate, leaving a political deposition of value beyond the scientific measurements that are made.

National Aeronautics and Space Act of 1958, as Amended

The basic foundation for the civilian space program is Public Law 85-568, the National Aeronautics and Space Act of 1958. This act was the result of compromise, but represented a victory for those who supported a space program conducted principally by an independent civilian agency. The policy guidance in the act, essentially unchanged from its original form, specified that "activities in space should be devoted to peaceful purposes for the benefit of mankind." It also enumerated a set of broad objectives:

- Expansion of human knowledge.
- Improvement of aeronautical and space vehicles.
- Development and operation of vehicles (spacecraft).
- Study of potential benefits to be gained from aeronautical and space activities.
- Preservation of the role of the United States as a leader in aeronautical and space science technology and their applications.
- Publication of information about discoveries.
- Cooperation between the United States and other nations.
- Effective utilization of the scientific and engineering resources of the United States.

Significantly, the act is silent on responsibilities for operational space systems beyond DOD's role with regard to national defense. By implication, since the "aeronautical and space activities" that are the principal responsibility of NASA, are defined as "research . . ., development, construction, testing, and operation for research purposes of aeronautical and space vehicles, and such other activities as may be required for the exploration of space, " operational roles are expected to be carried out by other agencies. At the time the act was written, however, its framers did not foresee the variety of space applications that are now possible. That the act neither specifies nor precludes operational responsibilities for NASA suggests a pragmatic approach to each functional area and a flexibility in determining which agency should take the lead in operating any given system. (NOAA's current assignment as the lead agency for Earth observational satellite systems in the civil sector may also need reexamination and evaluation in the light of its activities since assuming this role about a year ago.)

This report presents a more detailed summary of the 1958 NAS Act in chapter 3. The following observations are appropriate here, however. The legislative mandate for NASA has had great effect on the institutional configuration of the agency, but has provided little guidance on the pace and content of the program. In some areas, notably space communications R&D and Earth resources systems, the act was of no use in resolving policy differences or in guiding executive branch action. Recent congressional action, such as in the energy area, has been much more aggressive in spelling out the objective of technological programs and giving guidance on the level of intended or expected spending, but not all such efforts represent a good legislative model. Clearly, a balance between a detailed congressional mandate and a restrictive overspecification of the program must be struck.

The Apollo Commitment

No other single event has so profoundly shaped the U.S. space program and current issues as the decision for man to go to the Moon and return within the decade of the 1960's. Much has been written about the personalities and pressures that led to Kennedy's decision, and that discussion will not be rehearsed here. The most important aspects of Apollo for this assessment are its legacy and the issues flowing from that legacy.

The major characteristics of the Apollo proposal were:

- A multiyear joint executive branch and congressional commitment.
- An extremely challenging technological feat, feasible in principle, but with a great many engineering problems, and under a significant time constraint.
- A political measure–aimed at foreign policy goals, national prestige, and self-confidence.
- Commitment to a major expansion in the civil space program and in the institutional base for the program.
- Required contractor teams on a scale not previously attempted.

In the process of accomplishing its goals, NASA added significantly to its laboratory structure, creating a combined Government-contractor work force that exceeded 400,000 people at its peaks Though Apollo dominated the agency's priorities, there was also a presidential commitment to pursue satellite communications and meteorology, and programs in these areas also expanded during the 1960's. During this period, many were strongly attracted to the challenge and the promise of space activity.

However, even before the first successful lunar landing, there were signs of change. NASA budget outlays, which peaked at nearly $6 billion in 1966, began decreasing by almost $500,000 a year for the next 4 years. The total work force dropped from 400,000 to 160,000 in the same period, beginning a period of aerospace unemployment that was to have significant impact on future commitments to manned flight programs. (Of the decrease in aerospace employment over this period, over 220,000 was in direct contractor employment, while only 6,000 was in civil service or direct support service manpower.) A backlash developed in the scientific and engineering professions when individuals found that their opportunities for careers in aerospace were

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[5] *The U.S. Civilian Space Program—look* at options. OMB Issues **Paper, Oct. 14, 1971.**

disappearing. During the peak readjustment period, the political liability of large-scale unemployment in this work force prompted direct, Government-supported, ameliorative measures. As a result of this expansion and rapid contraction in the aerospace industry, political resistance to future decisions causing major disruptions in the work force may be anticipated. (See discussion of the space shuttle decision below).

During the decade of the 1960's, therefore, the overarching commitment to Apollo focused the space program; other space activities throve amidst Apollonian largesse. By the beginning of the 1970's, however, the program had lost its focus, and the continuing projects, all smaller in scope, began to lose their way in the twilight of fiscal restraint.

The large-scale commitment to the Apollo program left a legacy that did not dissipate easily. This legacy, while mostly positive, was also somewhat disruptive because no equivalent subsequent project was identified. National prestige from such an amazing accomplishment continued long after the event, but ordinary citizens soon lost interest in space and began to ask: if we can put a man on the Moon, why can't we . . .

INTELSAT/COMSAT Commitment

Recognition of the importance of space platforms for communications came early in the space program. As the common carrier responsible for long distance communications in the United States, A.T.&T. funded a low-altitude satellite, Telstar, while Hughes Aircraft Co. constructed the Syncom series of satellites, which were intended for synchronous orbit placement. (The concept of a synchronous communications satellite was first suggested in 1945.[6]) With the beginning of the Kennedy administration and a much more activist role for Government in space, however, the role of the private sector was rewritten for the newly created COMSAT Corp., the chosen vehicle for U.S. participation in a commercial communications satellite system (a single, global system). NASA was to support COMSAT with R&D and with launch services, for which the agency was to be reimbursed. The COMSAT Act was passed in 1962, the first stock was issued in 1964, and its first satellite, Early Bird, was launched into synchronous orbit over the Atlantic in April 1965.[7]

In 1964, the INTELSAT Agreements were opened for signature, and COMSAT was designated the manager for the system. INTELSAT provided a means for gaining international agreement on the extent and type of services to be supplied, the charges for such services, the procurement policies, and a host of related matters. In the United States, where there is no single governmental entity responsible for providing telecommunications service, the relationships among the various potential suppliers of domestic satellite telecommunications services are regulated by the Federal Communications Commission (FCC). In 1970, after many years of debate, the principle of open entry and competition for domestic services was announced, followed by specific authorizations of domestic satellite services by FCC in December 1972,[8] which finally opened up the domestic market to a variety of suppliers of such services. The regulatory and commercial environment for domestic communications satellite services continues to change so as to affect the structure of the industry and the relationships among the various services and common or specialized carriers. In addition, maritime services have been initiated, backed by the U.S. Navy's guarantee to lease services from the system for defined periods. An international organization, INMARSAT, somewhat parallel to INTELSAT, was started for support of these services.

U.S. experience in the development of structures to provide services that exploit the capabilities of satellites has been unique from several standpoints:

1. New institutions were established: the quasi-public, domestic corporation, COMSAT, and the international entity, INTELSAT. Both

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[6] Arthur C. Clarke, "Extraterrestrial Relays: Can Rocket Stations Give Worldwide Radio Coverage?" *Wireless World,* October 1945, pp. 305-308.

[7] *Communications Statellite Act of 1962,* Public Law 87-624, 87th Cong., H.R. 11040, Aug. 31, 1962.

[8] *Comsat* @j& *to the Intelsat, Marisat, and Comstar Satellite Systems, 95* L'Enfant Plaza, S. W., Washington, D.C. 20024.

were important in gaining support and cooperation from other nations.

2. The Federal Government initially provided major support of R&D for communications satellite technology, in accordance with the act establishing COMSAT. The Nixon administration, however, as part of its policy of promoting more activity in the private sector, decided to downgrade NASA's program in satellite communications, terminating demonstrations of new spacecraft and substituting a low-level program of technology development. The Carter administration reversed field: NASA's R&D in space communications was to be returned to a higher level.
3. The aerospace industry played the role of major suppliers of satellites and ground equipment; NASA provided reimbursable launch services.

Before the space age, the communications industry was already well established: the outlines of its structure were fairly clear; the services it provided were well understood; and regulations governing its activities were in place. A new technology, space satellite communications relays, revolutionized the industry: space provided a unique, high-altitude vantage point, to and from which a variety of signals could be transmitted. Consequently, national policies had to be revised in order to cope with the new space systems.

The example of satellite communications shows that NASA's role in the R&D of applications technologies may be interpreted in several ways, depending on an administration's staging of the interaction between the private sector and the agency. This history indicates some lack of clarity in the legislative mandate. Willingness to take risks in forming new institutional arrangements (e.g., COMSAT or INTELSAT) can have a beneficial effect on development of a specific service. An organized user community, the readiness of a given technology, an established tradition of commercial services with an approximate value set for each—all are important factors in determining the success of a space application.

Weather Satellite Services

The use of satellites for global synoptic coverage of the Earth began with the experimental launch of Tires 1 in 1960, as a joint effort of DOD and NASA. This satellite's global cloud coverage pictures were the first in a long series, characterized by incremental improvements in succeeding satellites and by developments in their use in obtaining atmospheric and meteorological observations.g Because DOD's requirements were so different from NASA's, two separate meteorological satellite programs—one civilian, one military —were established. NASA's satellites were integrated into the Federal Government's system for providing U.S. users with information regarding local and synoptic weather. These satellites also provided weather data to other nations and to international entities. Here, as well as in other civilian applications services, NASA led the way in identifying appropriate technologies for air and space platforms. In the case of weather satellites, the relationship between NASA and its user agency was a somewhat turbulent one, occasioning considerable interaction and debate before a suitable working relationship was developed. For weather satellite services, NASA functions as a launching agency and also provides (through coordination with the user) the early experimental development of satellite sensors and platforms. These are, at a suitable time in their evolution, incorporated into operational systems for whose management the user agency, currently NOAA, is specifically responsible. (The present good working relationship between NASA and NOAA forms the background for the decision to assign operational responsibility for civil operational Earth resources sensing to NOAA.) The major patterns that emerged from the early experience with weather satellites were:

- Strong ***Government role.*** NASA developed and NOAA operates a primarily civilian service.

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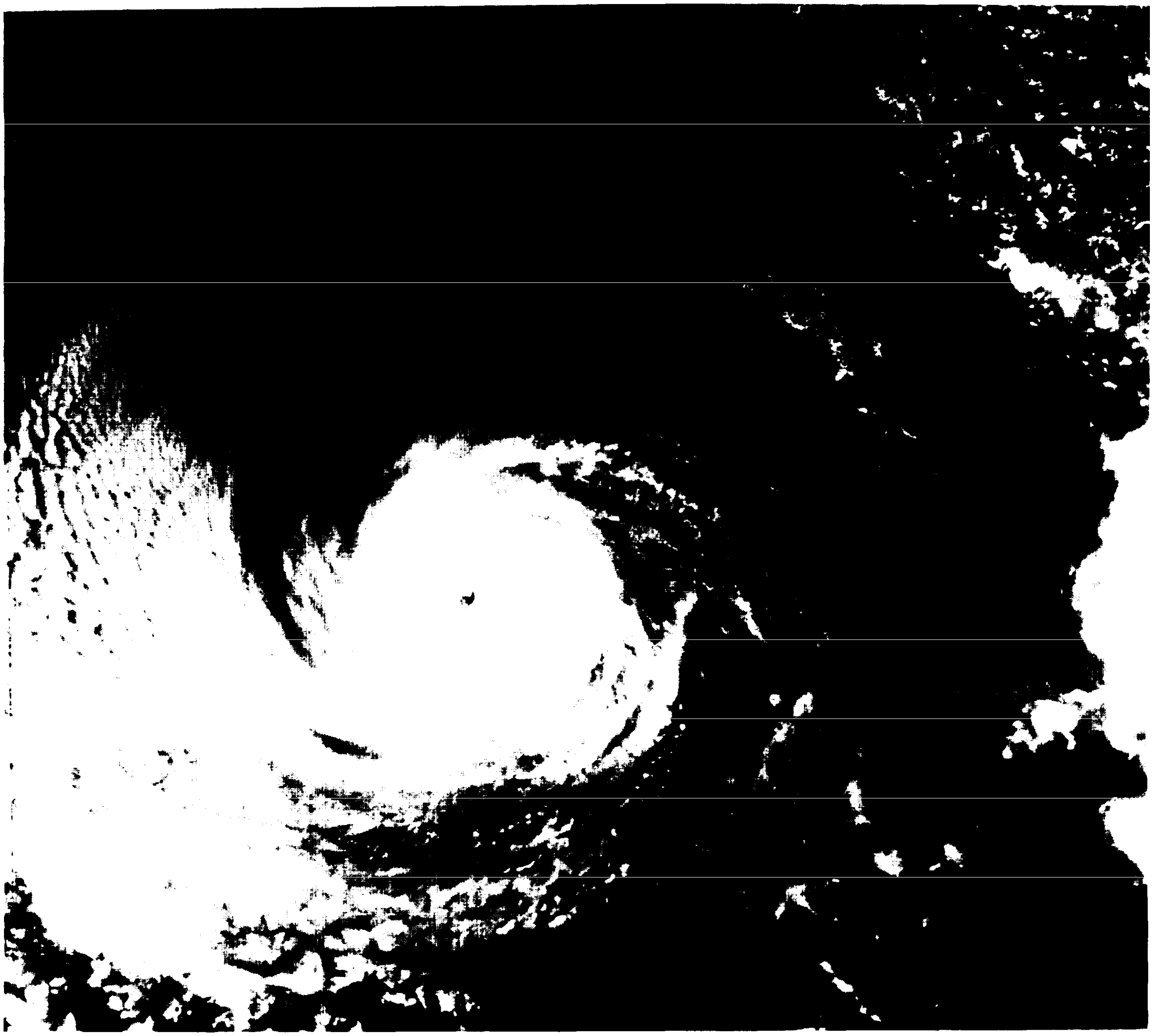
[9] *NASA News,* Capsule History of Weather Satellites, Release No. 76-1 46; National Aeronautics and Space Administration, Washington, D.C. 20546,



NOAA's weather satellite (SMS-2) photographed hurricane Katrina off the coast of Baja, Calif., Sept. 3, 1975

- *Weather data distribution is a public service.* Data are supplied to non-Government users at cost of reproduction, the Government bearing the entire cost of development of the system and of collection and dissemination of data.

- *Separate civilian and military weather satellite systems.* Similarity of the measurements taken for the civilian and the military systems prompts periodic review of the standing proposal to join them. These reviews unfailingly conclude that specialized military applications require an independent program. Likewise, the very different requirements of the civilian system—widespread dissemination of uncensored data over various users in the United States, and interaction with the international meteorological community—militate against a merger.

- ***Extensive cooperation with other nations.*** The United States participates in large-scale experiments and provides open and ready access to the results.
- ***Open data policy.*** Data are supplied worldwide to"all users.

Because of the doubtful commercial potential of weather satellite services, the Government's role of operator (as well as developer) of weather satellite systems was not controversial. As a result, the weather program, unlike the Landsat program, has sparked no debate over management structure, data handling, or pace of development. If the data provided by the weather programs were to be of commercial value, they would require additional processing and integration with other, related data. Until the recent COMSAT interest in assuming ownership of the meteorological satellites along with the Landsat system the possibility that the private sector might convert such data collection and interpretation to its own use seemed remote.

The weather satellite program has shown that global cooperation has been most active and effective in meteorological and weather services–areas where commercial and national security interests are muted. Relations among NASA, NOAA, and the user community demonstrate that it is possible to have separate R&D, operational, and user responsibilities, and yet to maintain a viable service. Reasonable technological progress has been made under this arrangement. Separate military and civilian programs have existed because of differing user requirements, and prospects that military and civilian users can make greater use of common data streams, channeled separately to each, must remain subject to periodic review.

Scientific Research and Exploration

As pointed out in the section on the international Geophysical Year, the initial rationale for the U.S. civilian space program was based on the need for scientific research in space. A continuing strong, science-based program has been characteristic of the civilian space effort since its very beginning. There are some important features of the science program that require further comment:

- ***University participation.*** The major participants in science programs have been university-based experimenters who provided the basic ideas for measurements to be made and, in some cases, the basic designs of the instruments to be flown to make these measurements. Commercial interest is almost invisible, and the principal competition for experimenter roles is between government laboratory scientists and university science teams.
- ***National Academy of Sciences.***[11]The National Academy of Sciences, through its Space Science Board, has done much to set the agenda for space science, identifying both a general rationale for many measurement programs and the specific nature of the most attractive experiments. The Academy's pronouncements have also had a major role in such areas as lunar quarantine and planetary contamination, even to the point of stimulating major investments for such items as a quarantine facility for handling lunar samples and astronauts on their return from the Moon. In planetary programs, the Academy's recommendations were instrumental in determining the criteria for judging the acceptable degree of risk that Earth micro-organisms might contaminate a planet's surface. The Academy's influence was reflected in the programs by the requirements for prolonged heat soak sterilization, for spacecraft encapsulization, and for selection of acceptable trajectories of approach to the planet.
- ***International cooperation.*** Historically, the science program has been international in scope, and it appears to be moving toward even greater international cooperation in the

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[10] J. V. Charyle, testimony before the Subcommittee on Space Science and Applications of the Committee on Science and Technology, U.S. House of Representatives and the Subcommittee on Science, Technology and Space of the Committee on Commerce, Science, and Transportation, U.S. Senate, July 22, 23, 1981.

[11] *Outer Planets Exploration,* 1972-1985, National Academy of Sciences, Washington, D. C., 1971, and *Opportunities and Choices in Space Science,* 1974, Space Science Board, National Research Council; National Academy of Sciences, Washington, D. C., Nov. 11, 1974.

design of missions and the development of experiment payloads.

- ***Difficulty of keeping project teams.*** As missions become more complex, expensive, and international in flavor, and as the time between mission opportunities grows, it becomes increasingly difficult for U.S. science teams to remain active and involved with the program. Even assuming that only the best teams are retained, there is nevertheless a narrowing of the base from which new experiments and ideas originate, with resultant long-term negative impact on the quality of NASA's science effort. Fewer flight opportunities also may bring about a subtle leaning toward NASA experimenters, although it is intended that there be no bias toward the in-house groups; and
- ***Emphasis on spacecraft.*** The tendency within NASA has been to focus on development and launch of the spacecraft and its payload, and its operation to obtain the desired data. Data analysis and interpretation and continuing exploitation of the information or material from these missions tends to be given lower priority and is almost always in need of greater budget support.

Post-Apollo Planning

In the mid-1960's, planners from NASA joined PSAC, which had kept a close involvement with space policy (despite being overruled at critical points such as the choice of lunar landing mode) to look toward the post-Apollo period and to consider possible courses of action. In February 1967, PSAC published a comprehensive report attempting to answer the basic question, "Where does the Nation go in space in the post-Apollo period?"[12] Consistent with the major emphasis of the civilian program started by Apollo, one of the major preoccupations of that report was the future evolution of the manned flight program, for resolution of this issue would affect the budget more than any other. The advisory panels that drafted the report were acutely aware of the importance of Apollo in stimulating a very vigorous and broad program, and recognized that the next step of equivalent scope would be a commitment to manned planetary exploration. They did not, however, endorse such a commitment. Instead, they recommended a more balanced program in which manned planetary exploration was still very much in the long-term picture, but which would place greater emphasis on unmanned science and applications missions in the short term. Manned flight would continue, but at a much more leisurely pace. Interestingly, the report recommended work toward a space station module in the mid-1970's, but suggested that this date could slip depending on the pace of a national commitment toward manned planetary exploration. The major justification for such a station was long-duration studies of how humans react to lengthy exposure to the space environment. In the foreword to the PSAC report, the President set a conservative tone, stating that the "opportunities in space are great but the costs are high . . . " without endorsing a future program or set of new guidelines.

NASA pressed forward with ambitious plans for post-Apollo lunar exploration, further development of the space station, manned planetary flight options using Apollo-based hardware and exotic new systems, such as the nuclear rocket then under development. No approval of such plans was forthcoming from a Johnson administration that was preoccupied with the costs and public impact of the Vietnam conflict. Thus, the dramatic decline in NASA budgets mentioned earlier began. Although NASA planning was somewhat fragmented among the various program offices and lacked coherence, the problem resulted principally not from a lack of planning, but rather from a failure to generate consensus on what the Nation wanted from its civilian space program and was willing to pay for.

Long-range planning exercises can have a beneficial result because they help to clarify the options and develop consensus on what the next steps should be. However, they have little effect on obtaining political and budgetary commitments, which often appear to depend more on external factors such as national or international crises.

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[12] *The Space Program in the Post-Apollo Period*, a Report of the President's Science Advisory Committee, the White House, February 1967.

Earth Observations

The experience gained in flying weather satellites and from military reconnaissance programs (not publicly discussed at that time because of a policy decision to protect the "fact that" such activities were taking place) indicated both the feasibility and value of Earth observations, provided there was sufficient resolution either spatially or spectrally to evaluate the nature of the observed scene. J Since there were multiple uses and users for Earth observation data, and no one single user appeared to have a dominant role or need, there was considerable delay between recognition of the value of satellite remote-sensing observations and the initiation of a program to obtain them from space. There were a number of reasons for this delay. Among them were:

- ***Concern by the national security community*** that there would be some international protests if sufficiently high-resolution civil data were to be collected that would have intelligence/military value. This was resolved by setting a limit on the resolution permitted for any civil system;
- ***Lack of a clear lead agency responsibility.*** The Department of the Interior tried to solve this problem in 1967 by announcing an EROS satellite program for Earth observations primarily of geological interest, but this announcement was made without obtaining White House, Bureau of the Budget, Office of Science and Technology, or National Security Council (NSC) approval. Consequently, it was killed quietly (largely because these approval and coordination steps had not been taken) in the budget process. NASA had the responsibility for the necessary R&D, and the weather satellite experience demonstrated that a suitable working arrangement could be established between the R&D leader and the operator and user. NASA began to exercise this role and pull together the various potential users in connection with the definition of the experimental Earth Resources Technology Satellite (ERTS). But this effort occurred at a time when the general attitude toward space ventures was changing from the expansionary vision of Apollo to a more conservative and cost-conscious approach. The recommendations of PSAC are indicative:

  > . . . a reasonably clear case of potential utility must be made, which includes potential economic benefit, before significant development costs are assumed.
  >
  > .,. space technology has passed the point **where the demonstration of mere feasibility of a particular application has any technological or prestige significance.**[14]

  In this environment, NASA was initially unable to provide credible cost-benefit data and user contributions that would substantiate the need for such a system. Further studies ensued, more user support was enlisted, and still the case for ERTS did not appear persuasive. Finally it was approved, largely on faith that existence of a real data stream from the satellite would stimulate uses (and users) enough to build a positive cost-benefit case to proceed toward an operational system.

Opposition from those who supported aircraft for Earth surveys. While not as significant as the factors mentioned above, the active promotion of the use of high-altitude aircraft as an alternative to spacecraft platforms showed the acceptance of satellite remote sensing. The arguments about the relative merits of each approach are not important to this assessment, but it is significant that aircraft data collection would probably have been carried out by one or more private contractors whereas ERTS required NASA management, direction, and participation in data handling, spacecraft operational control, etc. While NASA opposed reliance on aircraft, it nevertheless recognized their value and subsequently organized a substantial high-altitude aircraft program based on the U-2. Of course, the ease of global coverage for a satellite as compared with an aircraft was not contested. It was simply unclear at that

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[13] *A Retrospective on Earth-Resource Surveys:* Arguments About Technology, Analysis, Politics, and Bureaucracy. U.S. Arms Control and Disarmament Agency; Photogrammetric Engineering and Remote Sensing, vol. 42, No. 2, February 1976, Washington, D.C.

[14] *The Space program in* the *Post-Apollo Period,* PSAC, February 1967.

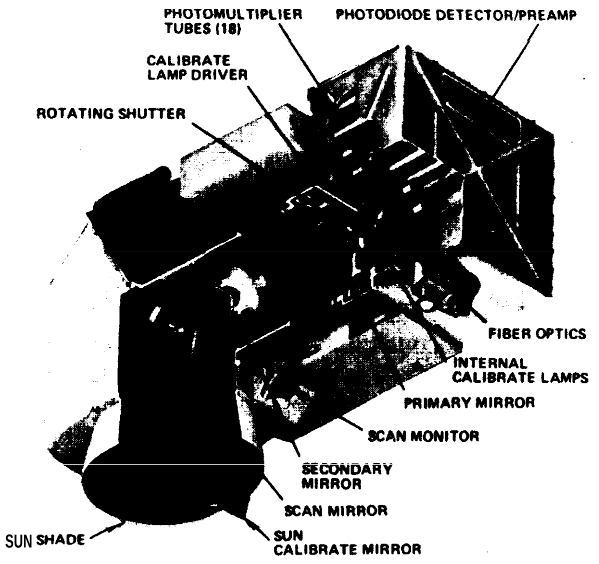

Photo credit: National Aeronautics and Space Administration

Cutaway view of the multispectral scanning system

time how ERTS data on other countries would be collected and used, particularly in a processed or interpreted form.

- ***Lack of an organized user community in the private sector.*** Much of the early interest in Earth observations from space centered in Federal Government agencies whose missions could be accomplished more effectively if satellite data were available. Neither State and local governments nor potential users in the private sector were willing to make early commitments. In each category, there was a typical pattern: the potential user might find the data useful, but was largely incapable of analyzing his needs or even of conducting the research necessary to understand them more adequately. Therefore, NASA was funded to support a wide array of user experiments as part of ERTS-1, in order to improve the base of understanding of the value of the satellite output. (Lack of an organized and established user community for ERTS, or Landsat, as it was renamed, contrasts with the situation for early space telecommunications services where the entities for long-haul telephone services already existed. Similarly, there has been no institutional innovation for Earth sensing, either nationally or internationally, as there was in the case of COMSAT and INTELSAT.)

Space Task Group

At the beginning of the Nixon administration, the Apollo program was rapidly coming to a successful close, but no clear definition of a post-Apollo space program had emerged. Early planning efforts had failed to yield a consensus, and space program budgets had decreased dramatically, presenting the new administration with growing unemployment in the aerospace industry as well as a major technological agency that did not have clear signals regarding its future. in order to address these problems, the presidential Space Task Group (STG) was established under the chairmanship of the Vice President. The STG review was the first comprehensive interagency planning effort that was carried out with respect to the civilian space program. It also included a component directed toward future military applications in space and was subject to special security classification restrictions. Its principal focus, however, was on the future nature and pace of activities in connection with the civilian manned space flight program, While NASA's leadership was not particularly pleased to have its future programs become the object of an interagency planning effort, it recognized the need for broader consensus regarding its future objectives, particularly because the new administration had made no budget commitment. (This lack of budget commitment was a continuation of the trend that had begun in the Johnson administration.) The assignment for STG included taking a rather long-range perspective extending out through the decade. As in the earlier review by the PSAC, a key issue was the question of whether to propose a new manned mission to the planets.

In their recommendations, STG recommended commitment to a balanced program that included science, applications, and technology development objectives, but no immediate commitment to manned planetary missions. They sug-

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[15] *The Post-Apollo Space Program: Directions for the Future*, Space Task Group Report to the President, September 1969.

gested no change in institutional structure nor an operations role for NASA. Emphasizing international cooperation, STG was given special emphasis and it was suggested that NASA should give greater attention to possible cooperative opportunities. The major technological development STG suggested was the reusable space shuttle system that could eventually lead to development of a permanent space station. The clear priority was for shuttle development first, with space station modules as a potential future technical development. Manned planetary exploration was retained as a long-range option for the civilian space program with a "manned Mars mission before the end of this century as a first target."

STG presented a number of budget options in connection with these recommendations, permitting the program that was recommended to be carried out at several rates. The response to STG recommendations was not immediately forthcoming. The President's advisers, faced with other serious budget and international relations problems including the Vietnam conflict, deferred action on the basic recommendations until the subsequent budget cycle. At this point, in a very general response to the recommendations, the clear image of a relatively conservative and constrained program emerged. New mission commitments were folded into a general ceiling for the agency that was established at slightly above $3 billion.

The Space Task Group effort was notable for a number of reasons:

- It was the first major interagency planning effort with regard to the civilian space program.
- It involved participation from the general public as well as agency representatives.
- OMB was involved, with the explicit reservation that its participation would not preclude its normal budget review and analysis when specific budget requests were proposed.
- It was comprehensive in including both DOD as well as NASA interests, particularly with regard to launch vehicles.
- it took a long-term view, specifically focusing on the next decade.
- It did not attempt to seek a single consensus on the program level, but rather provided a number of options from which the President could select.

STG provides an interesting example of the difficulty of making long-term plans for the space program. The administrator of NASA was obviously in a position that he would have rather avoided (it being certainly less difficult to deal with a single OMB review on the budget and program than to obtain consensus from an interagency group, several members of which may have competitive objectives). Hence, STG represented, on the surface, a very difficult forum for presentation, analysis, and eventual development of a consensus on the NASA program. In this forum, the view of both NASA and DOD representatives tended to favor continuing large-scale space investments with a multitude of new systems identified by their technical laboratory and supporting contractor structures. A more restrained note was set by OMB and OSTP representatives. As the deliberations in STG proceeded, the question of a major new focus for the civilian program in the next decade, equivalent to the role that Apollo played in the previous decade, became a major issue.

In general, STG believed that the technology existed for a manned Mars mission and that such a mission, if accepted as a new goal, could serve to energize and focus attention on the space program in a beneficial way. The Vice President became convinced that such a mission would be an exercise of leadership which he viewed as missing from the space area and he supported this goal as a target. He was not able to convince the remaining members of the task group that this goal was realistic, and acceptable to the public, but it was endorsed in a somewhat ambiguous way as a "potential" goal or "option" for the program. In this way, it could serve to guide decisions regarding the development of new capability for man in space. In STG'S recommendations, the terminology was chosen very carefully in order to maintain an option for the Vice president and the Administrator of NASA to make further appeals that would support their program objectives and yet have a report to the President that all STG participants could approve. In addition, there were certain "code words" that were used that had considerable significance beyond their direct connotation. For example, the use of the term "new capability" implied very specifically a development program that would involve a manned, reusable launch vehicle as the first major element. On completion of this first development, the next major commitment would be to a continuing orbital habitat for man, i.e., a space station. The order in which these new systems would be developed was a major source of controversy within STG, and the eventual agreement on the shuttle as the first element represented a major change in direction within NASA.

The space shuttle appeared to be a logical and most effective way to maintain the capability for continuing use of man in space while simultaneously providing a capability for launch and recovery of unmanned space payloads as well. At the time, the space shuttle was not completely defined, but its essential and desirable operating characteristics were clearly spelled out.[16] The alternatives for maintaining a manned flight capability were: continued use of Apollo hardware in the future, wherein the cost and reliability of each succeeding hardware set would become more difficult to predict; or the development of a new capsule and launch vehicle combination such as the Titan III, a modified Gemini system.

Overall, STG accomplished several important objectives. It clarified the nature of the major options facing the Nation with regard to the space program. it identified the rough costs associated with pursuing many of these options. It suggested several new emphases for the space program (international cooperation, new systems that were reusable) and the increased development of applications. it made a clear call for continuing the man in space program and suggested the logical steps in that program. However, it did not proclaim a specific new Apollo-type goal. As a consequence, in the minds of many space enthusiasts, it did not go far enough. On the other hand, to those who were concerned about the magnitude of space expenditures and questioned the value gained from those expenditures, the STG report appeared to be too optimistic, too positive regarding the nature of new space opportunities. This ambiguity permitted individuals with somewhat different perspectives to see in it what they wished to see while the report retained some of its essential characteristics. Specifically, it permitted the Vice president to advocate a vigorous new commitment such as a manned mission to the planets before the end of the century and OMB to look at a program which eventually was projected at a very modest continuing budget level. STG issued its report as a public document after briefing the President, and it was in this period that public and congressional response was evaluated to determine the nature of the commitment that could develop around the concepts that were proposed. It was only later, in the context of specific budget reviews, that the decisions would be taken on the STG recommendations.

Interagency reviews can serve to build a constituency for space program initiatives. For example, the STG recommendation focused attention on the space shuttle program as the next major step in technology development. NASA in-house planning exercises do not appear to have the same effect. A key element is participation by elements of the Executive Office of the President in order to bridge the communications gap from agency to President. Such reviews are not sufficient to generate a political commitment to costly new programs, but may be a necessary precursor.

The Shuttle Decision

In the period immediately after the STG report, NASA programs continued with no major new commitment to a new development. During this period, the attention of the agency was focused on completing revisits to the Moon using already developed and purchased Apollo hardware, and using a modified version of this hardware in a prototype manned habitat called Skylab.[17] Skylab was an effort to stretch the utility of Apollo hard-

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[16] *New Space Transportation Systems,* an AIAA assessment, Jan. 9, 1973. American Institute of Aeronautics and Astronautics, 1290 Avenue of the Americas, N. Y., New York 10019.

[17] *America's New Decade in Space,* a report to the Space Task Group prepared by National Aeronautics and Space Administration, September 1969.

ware, demonstrate manned flight in Earth orbit over a prolonged period, and perform a number of operations, including observations with a solar telescope, During this period, NASA was given initial exploratory funding for the space shuttle design and early development work on a new liquid hydrogen-liquid oxygen, high-pressure rocket engine that would be suitable for a shuttle. The need to make a major commitment to the shuttle came to a focus in the context of the review of the fiscal year 1973 budget that was carried out in the fall of 1971. At that time, the reelection campaign of 1972 loomed on the horizon for the Nixon administration. Also at that time, unemployment in the aerospace industry was a major political embarrassment, and the review of the NASA program in the fall of 1971 gave particular attention to the short-term employment picture. NASA was by this time committed to a shuttle development program as the next major step in the advancement of space technology. Also developed by NASA was a major economic evaluation of the shuttle based on an elaborate mission model that projected missions in various categories of activities out through the end of the decade. In NASA's presentations, the economic benefit of proceeding with a space shuttle was part of its argument in favor of adopting this program. To the analysts in OMB, however, this argument was unpersuasive, because, in part, shuttle development costs were highly speculative and the mission model contained a large number of questionable assumptions about the civilian program. In the analysis for the fiscal year 1973 budget, the major issue was whether or not the United States should continue with a manned flight program, and if so, with what technical systems. OMB concluded that the United States would derive a majority of the benefits from space activities without a manned flight component. However, this decision would have had dramatic impact on the nature of the NASA establishment (resulting in the closing of at least two major centers) and would have lowered NASA budgets to approximately $2 billion or less per year. At this rate, there could still be a very vigorous unmanned science and applications program. Manned flight, on the other hand, could be continued, either with modified and extended Apollo hardware, with a new-generation space capsule, or as part of a space shuttle program in which man would be involved both as a pilot and as a participant in Earth-orbital experiment programs (including the launch and recovery of unmanned satellite systems from low-Earth orbit).

A firm commitment to the space shuttle remained an open question until the very last Presidential decisions were being made on the fiscal year 1973 program. During this period, the employment impact of a positive decision on the shuttle was analyzed in great detail. In January 1972, the President made a well-publicized commitment to a space shuttle development program. This commitment was constrained by some key guidelines:

- The shuttle would be carried out under a budget target rather than on the basis of a schedule that had to be met. The budget target that was eventually agreed to was for a considerably scaled-down shuttle from the one originally projected by NASA, with a development program cost targeted at slightly over $5 billion in constant 1971 dollars.
- The shuttle was expected to be a "national" program, that is, it would serve all agency launch needs for payloads that were in the shuttle range. Specifically, this requirement implied that NASA and DOD would need to define a common, acceptable payload bay size, operating characteristics, and compatible subsystems. (At the time, the questions to be resolved included whether DOD would have its own shuttle orbiter, whether DOD would have its own crews, whether classified payloads would be incorporated with an unclassified payload, etc.) The major premise was that such a substantial investment in a new technological capability could not reasonably be made unless it would serve or be capable of serving the broadest set of national needs.
- The initial concept included the possibility that DOD would assume some degree of funding responsibility for shuttle development. This was subsequently modified in view of the rather substantial DOD budgets already in existence for other weapons systems and space developments. It was agreed

that DOD's share of the program development costs would be limited to DOD funding for the west coast launch site for the shuttle and a companion interim upper stage development for boosting shuttle payloads into higher orbits.

- International cooperation in the shuttle program was also an objective; it was satisfied by the eventual agreement that the Europeans would construct a laboratory module to be carried as a shuttle payload.

The shuttle decision was a multiyear development commitment, not as aggressive or substantial as NASA would have liked, but yet ensuring the continuing utilization of the technical development and management capabilities of the Johnson and Marshall Space Flight Centers and a new development activity for the Kennedy Space Center. Most viewed the shuttle as a program that would act to stimulate some technology development, but would not be so complex or difficult to achieve as to be threatened by major overruns or schedule delays. The shuttle had great potential for changing the way people would think about placing payloads into space; e.g., it would change the design of these payloads to allow reuse and repair, it would permit human tending and space checkout prior to launch into orbit, it would increase the flexibility of space operations to allow larger crews and potentially less-trained scientific personnel to conduct operations in space, and ultimately it would be the key to any continuing Earth-orbital habitat for man, since it would provide resupply at a much more reasonable cost than use of expendable vehicles.

On the negative side, the President and Congress recognized that initiating shuttle development and terminating the limited program utilizing existing Apollo hardware would result in a hiatus in manned flight for a period of 4 to 5 years. During this period the Soviet Union would have an opportunity to initiate new space spectaculars with uncertain international and domestic political impact. The commitment to substantial shuttle development funding within a constrained NASA budget implied an additional problem. As part of the shuttle commitment, NASA was given some assurance it could plan on level budgets, in constant dollars, for the duration of the shuttle development program. Thus, growth in shuttle funding requirements would have a tendency to squeeze out other new programs. It was this aspect that was viewed with great alarm by those who supported greater emphasis on space science and applications activities. Thus, the shuttle decision was not a completely happy one in this community. One of the most important lessons to be learned from the shuttle decision is that a commitment to continued manned space flight has the greatest budget impact and is the most politically driven part of the space program. Such factors as aerospace employment or national image therefore have a strong bearing on

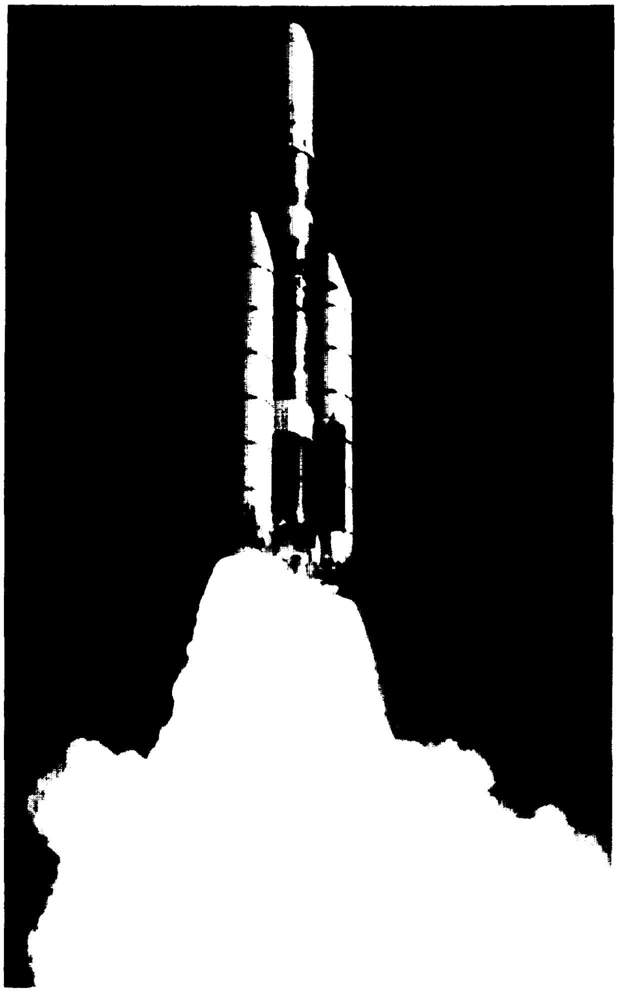

Photo credit: Nationa/ Aeronauts and Space Administration

Air Force *Titan ///-C* lifting off to **launch Applications Technology Satellite 6, May 30, 1974. The first** in a **generation of NASA communications satellites**

decisions that are made and must be factored into the technical aspects.

Communications R&D Decision

NASA responsibility for a leadership role in developing space capabilities, performing the necessary R&D in all of the areas of interest involving space systems, had included an early and substantial role in developing the basic technologies that were vital to the increasingly sophisticated civilian communications satellite business. These technologies were demonstrated in a series of applications technology satellites. The technologies included advanced stabilization techniques, the control of satellite position in synchronous orbit and, in the last satellite of the series, a demonstration of broadcast technology from the satellite to small, low-cost ground stations.

The second of these broadcast satellites that was scheduled to be launched was terminated by OMB. Additionally, OMB acted to reduce significantly the role of NASA as developer and demonstrator of advanced satellite telecommunications technology. The leadership for this change in emphasis came from the Office of Telecommunications Policy (OTP) and was consistent with the trend to place greater responsibility in the private sector for telecommunications systems developments. The assumption underlying this decision was that NASA's contributions were not necessary to maintain the sophistication of current and projected communications satellite systems. In addition, OTP believed that the revenues obtained from satellite communications to support work in the industry at such technical centers as the COMSAT Laboratories were sufficient to enable incremental improvements to be made during the foreseeable future. DOD's R&D role in telecommunications satellites was not similarly reduced, and it was expected that DOD would continue to support technology advances in this area.

The most immediate effect of the decision was to stimulate the technology development activities of a number of potential foreign competitors in the telecommunications satellite area, because the basic approach of U.S. industry was to continue to exploit the proved technologies that were available and to package these technologies in larger and more capable satellites. Thus, in the intervening years, the telecommunications technology advancements that were typically a responsibility of NASA have for the most part not occurred in the United States. Starting from a very inferior technological position, the Europeans and the Japanese have built considerable competence in this field, and in some areas appear to have leapfrogged U.S. technology.

The decision of the Carter administration to return more responsibility to NASA for R&D in satellite communications provided, somewhat belatedly, that the agency would again assert itself in this field as an agent for technology push. NASA has interpreted its charge to mean that satellite systems initiated under this new, invigorated program should have a potential direct application; the agency expects industry to support these programs to some degree. The current plan includes, first, development of collaborative agreements certifying to OMB that industry's interest is genuine, and second, provision that any demonstration system, if successful, may have a direct application,

Without Government support for high-risk applications systems R&D, the competitive posture of the United States may slip vis-~-vis other nations that do subsidize their industry. The current legislative authority for NASA does not preclude major reductions in its role as a sponsor of advanced R&D, suggesting an opportunity to clarify the meaning and significance of "leadership in aeronautical and space activities" as stated in the NAS Act,

President's Space Policy Statement of 1978

In october 1978, President Carter released a space policy statement that summarized the important aspects of the administration review of space policy and provided guidance regarding the President's view of national objectives in the space program over the next several years. This statement reaffirmed endorsement of a balanced space program and committed the administration to the continued development of the space shuttle system and its use during the coming decade. However, the statement made no new commitments and specifically rejected any major new technological development. No multiyear program or goal was set to provide a focus for the program and the general philosophy was best characterized by the statement that "activities will be pursued in space when it appears that national objectives can most efficiently be met through space activities. " Overall, the policy statement left many questions unanswered. It made several statements about what the United States would not do in space but remained very general regarding the nature of what we would do in space. In addition, it became clear that fiscal constraints were likely, and as a consequence, commitment to specific multiyear programs was very likely to be taken only with great care. This announcement was received with some dismay by the congressional leaders involved with the space program and by the aerospace community. This concern spawned a number of hearings and proposed legislative approaches to a more vigorous space policy for the United States and led to the request to. OTA for the current assessment.

NSC Policy Review Committee (Space)

The review of space policy undertaken by the Carter administration revealed that there was no procedure for adjudicating interagency disagreements about space issues. To remedy this defect, a policy review committee chaired by the Director of OSTP was established within the NSC structure to address such issues as might arise. This role had previously been played by the National Aeronautics and Space Council until it was abolished in 1973. An important consequence of utilizing the NSC structure is a rather strong orientation towards national security and military affairs. Issues arising in the civilian space program often have international importance, but as a matter of practice, they have been considered separately from those concerning national security or the military space program. The placement of this mechanism under the NSC provides a somewhat different flavor to the approach to civilian space policysetting. It is also important to note that this mechanism is intended to provide a means for resolving issues but not to provide planning or goal setting for space activities.

An alternative to the NSC structure would have been to conduct space policy review under the auspices of the Federal Coordinating Council for Science, Engineering, and Technology, a group that has a parallel function and is also chaired by the Director of the OSTP. The Federal Council has a charter, and is specifically charged with the coordination of activities among the principal agencies performing R&D, the recommendation of policy, and associated questions. Yet this mechanism was avoided in favor of the NSC setting. In part, this recognizes the great importance of space to the national security, the greater influence of the NSC, and the fact that the space policy review originally arose in the context of an issue regarding civilian/military space relationships.

Chapter 5

U.S. CIVILIAN SPACE PROGRAM

Contents

LIST OF TABLES

LIST OF FIGURES

Chapter 5

U.S. CIVILIAN SPACE PROGRAM

OUR DEPENDENCE ON SPACE

The extent to which the modern world in general and the United States in particular have become dependent on space technology is not generally appreciated. If the United States were to cease using space systems, day-to-day life and business activities throughout society would be disrupted. National security would be jeopardized as well. This section outlines the effects of doing without space, first in the civilian sector, then in the military sector. Tables 3 and 4 list the major U.S. space systems.

In the civilian sector, long-distance ***communications*** would be perhaps hardest hit. Already over two-thirds of all overseas telephone traffic is carried over satellite links provided by the international Telecommunications Satellite Organization (INTELSAT) system. Not only would private citizens be unable to complete many of their calls, but the rates for those calls completed would have to rise in order to provide enough capital to lay additional transatlantic cable to replace the capacity lost from satellite circuits.

News reporting all over the world would be severely restricted and delayed. Global television reporting would be out of the question, so that news from the international wire services would be restricted to stories and photographs that could be taped or transmitted as they were before the space age, through uncertain and congested ground links or via private courier. Newspaper editors in the United States would be left in the same quandary as their television counterparts, especially in receiving news from remoter regions such as the Middle East, South Africa, and Southeast Asia.

Domestic television service of the major networks would be severely curtailed, not only to relatively remote locations such as Alaska and Hawaii, but even within the continental United States, About two-thirds of all cable television service would be shut down, for much of both the basic-service national programing as well as premium pay-television programing is transmitted to cable television systems across the Nation via

Table 3.—U.S. Government Civilian Satellite Systems

Program	Orbit	Purpose
GOES *(2)*	Geosynchronous	**Meteorological**
NOAA (3)	Geosynchronous	**Meteorological**
TDRSS (first launch early 1983)	Geosynchronous	**Communications relay from other satellites to ground**
HEAO (High Energy Astronomy Observatory)	LEO	**Scientific**
NIMBUS	Polar	**Meteorological**
TIROS	Polar	**Meteorological**
Landsat-3	Polar	**Earth observation**
Landsat-D (mid 1982)	Polar	
DE (2)	(1) Elliptical	**Electromagnetic field observation,** space science
(Dynamics Explorer)	(1) LEO	Scientific
SBS (3)	Geosynchronous	Communication data, voice, video
RCA (4)	Geosynchronous	Communication data, voice, video
Comstar (4)	Geosynchronous	Communication (COMSAT) data, voice, video
Westar (3)	Geosynchronous	Communication (Western Union) data, voice, video
AT&T (2)	Geosynchronous	Communication data, voice, video
Marisat (3)	Geosynchronous	Marine Communication (COMSAT) data & voice

SOURCE: Office of Technology Assessment.

Table 4.—U.S. Military Satellite Systems

Program	Satellites	Functions
Defense Satellite Communications System II (DSCS 11)..	4 active 2 dormant spares	High capacity super high frequency communications. Part of Worldwide Military Command and Control System (WWMCCS).
Satellite Data System (SDS).	3	Carries AFSATCOM transponders.
Air Force Satellite Communications System (A FSATCOM)	Radio transponders carrod on SDS, FLTSATCOM (other satellites?)	UHF communications among National Command Authority, Joint Chiefs. Military Commanders in Chief, and nuclear capable forces.
Fleet Satellite Communications (FLTSATCOM).	3	UHF and separate SHF uplink. Naval Communications System operates over U.S. Atlantic Ocean, Indian Ocean, Contains some jam-resistant 5-KHz channels for AFSATCOM, 1,500-KHz channel for Presidential support for network of regional commands.
Defense Support Program (DSP)	3	Early warning of ICBM, SLBM launches by infrared detection of rocket plumes. Also carries visible light detectors and radiation sensors for detecting nuclear explosions. Provides surveillance of missile test launches.
Photographic Reconnaissance. . . .	2 types	Area-search and close-look remote sensing.
Electronic (Signals) Intelligence. .	At least 5 launches since 1973	
Geodetic Satellite.	6	Photographic mapping in three dimensions. Radar altimeter for topographical mapping of land and seacoasts.
Defense Meteorological.	2 block 5D spacecraft	Visual and infrared images satellite programs (most recent launch weather conditions, global failed) coverage four times a day.
Navy Navigation Satellite System.	TRANSIT (5 operating?) NOVA	Measurement in Doppler shift of radio emissions from satellites permits ship and aircraft navigators to find position.
Global Positioning System (GPS).	6 NAVSTAR (18 now planned)	Precisely timed radio beacons will allow users to determine position in three dimensions to within 10 m velocity to O.lm/sec.
Integrated Operational Nuclear Detection System (IONDS).	Aboard GPS, beginning with NAVSTAR 5	Detect and monitor nuclear explosions worldwide using bhangmeter sensors and GPS location data.
Space Detection and Tracking System	Ground-based cameras, radar, and radio receivers	Data funneled into Aerospace Defense Command Space Defense Operations Center, Colorado Springs, Colo. Identification and tracking of objects in space.

SOURCE: Office of Technology Assessment.

communications satellite transponders, Future plans for a variety of direct broadcast satellite television and information programs to private homes and businesses would be canceled.

Several less obvious services would no longer be possible. ***Weather reporting*** would be severely hampered; no synoptic view of large portions of the Earth from either polar orbits or from geosynchronous orbit would be available. These services are especially necessary for viewing the development of large weather patterns over the ocean several hundred miles off shore. Meteorologists would have to rely once again on piecing together fragments of weather observations from observation ships, radiosonde balloons, buoys, and light aircraft. Furthermore, observations of long-term changes in the ocean, atmosphere and polar ice would no longer be readily available. Without them, we could not predict long-term trends as well as we do now.

Navigation services would be significantly curtailed. Already more than 1,000 ships rely on satellite transmissions to ascertain their positions with great accuracy. Similar services soon to be made available for use in remote land regions would no longer be possible. Ship-to-shore and ship-to-ship communications via the global maritime satellite communications system (MARISAT) would be dangerously reduced; the task of the Navy, Coast Guard, and commercial ships on search-and-rescue missions would therefore be even more difficult. The International Maritime Satellite Organization (I NMARSAT) would have no raison d'être.

Satellite ***remote-sensing services,*** which have been important for the Departments of Agriculture, Commerce, and Interior, would be eliminated. No longer would satellite sensors be available to improve the management of the Nation's agriculture, forest, range, land and water resources—or to monitor large-scale catastrophic events such as the eruption of Mount St. Helens. Worldwide crop forecasting, an essential service for the U.S. agricultural sector, would be made much more difficult, nor would the United States be able to help developing countries to inventory and manage their own resources.

No longer would satellites be available for gathering data for studying the movement of air masses and the transformation of pollutants in the lower atmosphere. Similarly, of longer term concern, it would no longer be possible to monitor the chemistry, radiation exchange, and dynamics of the upper atmosphere in order to predict the long-term effects of human activities on these regions. Therefore, it might not be possible to know until too late whether man-made chemicals will continue to reduce the amount of ozone in the ozone layer, and what ill effects such a reduction might have on human life in this generation and the next.

The NIMBUS weather satellites of the National Oceanographic and Atmospheric Administration (NOAA) with their coastal-zone color scanners, would no longer observe the colors of the oceans over vast areas—revealing the murky green regions rich in plankton that are feeding grounds for schools of fish. Without this information, fishing fleets would expend 10 to 20 percent more marine fuel to locate their catches, and would pass along that increase in cost to the consumer as a higher price for seafood.

The search for new sources of minerals and energy resources would be curtailed; sensors under development, such as improved magnetometers or the multilineal array would not be sent into orbit. Without the data they promise to return, the ability to search for resources of long-range strategic importance, such as cobalt, titanium, and petroleum would be hindered.

Not only would all these applications become impossible, but many parts of ***space science*** would cease. No longer would spacecraft be launched into orbit to study the activity of the Sun or to observe the atmosphere and surface of the planets. In the absence of orbiting sensors and telescopes above the atmosphere to investigate radiation at wavelengths unattainable on Earth, ultraviolet, X-rays, gamma rays, cosmic rays, future understanding of the structure and evolution of the universe would be severely limited.

Meanwhile, in the ***military*** sector, many systems on which we rely for national security and for which adequate substitutes do not exist would be lost. Perhaps the most dangerous loss would be the capability to monitor the military activities of potential enemies. Surveillance satellites, which monitor the ground with high resolution at visible and infrared wavelengths, with synthetic-aperature radar, and by electronic "ferret" listening devices, are essential to ensure that foreign countries observe the terms of arms control treaties and to provide early warning of a nuclear attack. Military and diplomatic communications abroad and at sea would be slower, less reliable and less secure. There would be less ready access to high-speed instant communications between ground stations, field commanders, ships, submarines and long-range strategic bombers. Navigation and global positioning for military units would be deprived of the high degree of precision available through the use of positional satellite systems.

The way in which our society does business would be seriously affected by the loss of space. Not only would the availability of space services be cut off, but the revenue from those services would cease to flow. Perhaps hardest hit would be corporations in the communications business. Many of the major cable television operators would suffer, since their principal revenue flows from satellite-carried pay-television programmers such as Home Box Office, Showtime, and a dozen others. Furthermore, the loss of commercially sponsored "basic" cable programing beamed from satellite transponders would cause advertisers to cancel their commercials and withdraw their support-resulting in the bankruptcy of a number of programing sources. Western Union with its WESTAR satellites, RCA with its SATCOM satellites, would feel similar blows, although the impact would be somewhat lessened since the parent companies are diversified. Still, those employees directly connected with those companies' space segments—plus companies such as the Communications Satellite Corporation (COMSAT) whose entire business was related to space—would find themselves either idled or in desperate straits.

A final but important result of the dependence on space systems is that a large number of jobs and business opportunities would be lost if space activities ceased. Not only would future entrepreneurial activities in such areas as materials processing be cut off at the outset, the disappearance of space science as an existing discipline would wash up into the halls of major contracting centers such as the Jet Propulsion Laboratory in Pasadena, Calif., and in major universities heavily committed to space investigation (some 10 to 20). With the dissolution of the civilian space activities of the National Aeronautics and Space Administration (NASA), agreements with some 100 prime contractors would be canceled–forcing those contractors to cancel orders from subcontractors for specialized components. Since approximately two-thirds of the U.S. civilian space budget is awarded each year to private contractors, as those commitments disappeared some 50,000 jobs with contractors related to space would also disappear—undoubtedly adding a bit more burden to the unemployment rolls. Furthermore, those companies affected would probably retrench a bit on corporate advertising in various trade and lay publications. That loss in advertising revenue would cause a number of the heavily space-oriented publications to reduce the number of editorial pages in each issue and to perhaps contract their staffs.

Although many workers connected with space activities would probably find other employment (a good number in military and civilian high technology), an important infrastructure of expertise and experience would be lost. The future U.S. position in many areas of advanced technology would also be jeopardized—e.g., sensors, data analysis, precision control systems. in addition, through losing the extension of our society's collective eyes and ears throughout the solar system, and losing the heartpounding excitement of sharing an astronaut's launch and experiments in orbit, the United States would lose an important aspect of its shared national experience—the sense of adventure, confidence, self-esteem and world leadership provided by pursuing and ***succeeding*** at space activities over the past 25 years.

The conclusion of imagining what life in the United States would be like without space systerns is that it would certainly be very different and in many respects poorer. The extent of our present uses of space systems and the increasing promise of future uses of space technology argue that our dependence on space is great and will increase.

CURRENT STATUS AND PLANNED FUTURE ACTIVITIES

This section reviews the civilian space activities of the United States in Government, industry, and academia, and the direction those activities are likely to take in the near future (through 1990). Department of Defense (DOD) space activities are not treated in detail in this report except as they directly relate to the civilian program. Table 5 offers a glimpse of the generic space flight activities and spacecraft that have comprised the U.S. civilian program. Table 6 shows NASA's flight programs for the future.

Applications

Communications

Broadly speaking, satellite communications comprises point-to-point message, data, and video transmissions. It includes broadcasting from one point to many, distributed over relatively large areas; position-location activities such as navigation, traffic control, and search and rescue; and transmissions to, from, and among mobile transmitters and receivers (e.g., aircraft, ships, motor vehicles).

In the civilian sector, point-to-point satellite communications has been a commercial activity since the Communications Satellite Act of 1962 established COMSAT and designated it to represent U.S. interests in international, commercial satellite communication. The Federal Communications Commission (FCC) "Open Skies" decision in 1970 opened domestic satellite communications services to competition among commercial entities. Today (early 1982) there are four

Table 5.—Selected Groups of Civilian Spacecraft Launched by NASA From 1950 to 1980

Purpose	Spacecraft names	Sponsor (if not NASA)	Launches	
			Number successful/total	Years
Astrophysics	Explorer, Orbiting Observatories		*60/74*	1961-80
Planetary	Pioneer, Mariner, Viking, Voyager		*20/24*	1962-78
Communicaions—R&D	Echo, Relay, Syncom, ATS,		**13/16**	**1960-74**
operational	Intelsat, Westar, etc.	Commercial	**39/43**	**1962-80**
Meteorology—R&D	**TIROS, Nimbus, SMS (1)**		*22/24*	1959-78
operational	**ITOS, GOES, NOAA(2)**	**NOAA**	*19/22*	1966-80
Geodesy	**Explorer, PAGEOS, GEOS, LAGEOS (3)**		*717*	1964-76
Terrestrial	**ERTS, Landsat**		*3/3*	1972-78
Oceanography	**Seasat (4)**		1/1	1978

(l), (2), (3) **Also benefit oceanography:**

	Spacecraft	Sensor
(1)	TIROS-N	DCS, IR
	NIMBUS-5	MR
	NIMBUS-6	DCS, MR
	NIMBUS-7	CS, MR
	SMS	DCS

(2)	**GOES series**	**DCS**
	NOAA series	**DCS, IR**
(3)	GEOS-3	ALT

(4) Seasat sensor complement:
ALT, IR, MR, SAR, SCAT

Sensor key:

ALT	Altimeter
Cs	**Color scanner**
DCS	**Data collection system**
IR	**Infrared radiometer**
MR	**Microwave radiometer**
SAR	**Synthetic aperture radar**
SCAT	**Scatterometer**

SOURCE: National Aeronautics and Space Administration.

Table 6.—Selected Groups of Potential Future NASA Spacecraft

Purpose	Spacecraft names	Acronym	Earliest launch
Astrophysics	● 8 explorer-class satellites		1981-87
	● Space telescope		1985
	Origin of plasmas in Earth's neighborhood	OPEN	1987
	Gamma Ray Observatory	GRO	1988
	Advanced X-ray Astrophysics Facility	AXAF	1989
Planetary	● Galileo (Jupiter)		1985
	Halley Comet Flyby		1985
	Venus orbiting imaging radar	VOIR	1988
Communications–R&D	30/20 GHZ		1987
Meteorology—R&D	● Earth radiation budget experiment	ERBE	1984
	Upper atmospheric research satellite	UARS	1988
	NOAA next and GOES next		1989, 1990
Geodesy	Gravity Satellite (1)	GRAVSAT	1987
Terrestrial	● Landsat D & D'		1982, 1983
Oceanography	Topography experiment	TOPEX	1987
	Free-flying imaging radar experiment (2)	FIREX	1988

● These are the only spacecraft currently under development.

(1) Also benefits oceanography.
(2) Also benefits terrestrial.

separate domestic systems in orbit, with a total of 10 satellites, providing voice, data, video, and networking distribution services to a variety of clients: 1) the Comstar system of COMSAT General provides services to the American Telephone and Telegraph Co. (AT&T) and the General Telephone and Electronics Corp.; 2) the RCA American Communications system furnishes point-to-point and video network distribution services to private customers as well as to cable and terrestrial broadcasting systems; 3) Western Union's WESTAR supplies point-to-point services to private customers and video and radio network distribution services to the Public Broadcasting Service and National Public Radio; and 4) Satellite Business Systems (SBS) provides data transmission services to industrial organizations. In addition, several other firms, among them Fairchild Industries' American Satellite Co., Southern Pacific Communications, and Xerox Corp.'s XTEN, supply specialized communication services through transponders leased from satellite-owning corporations. Other firms, not in the business of transmission, lease satellite data or voice channels directly from members of other sets of carriers.

In addition, COMSAT General owns and operates the MARISAT system, providing message and data transmission services to ships at sea. Until 1973, COMSAT also managed the INTELSAT system, a global, commercial satellite communications system providing voice, data, and video transmission services to 103 countries. As manager for INTELSAT, COMSAT specified, procured, arranged for launch, and controlled satellites in the INTELSAT system. Under the definitive arrangements, entered into force in 1973, most of these functions have been taken over by the Director General of INTELSAT, assisted by an international staff, though COMSAT retains some responsibilities. Domestic carriers perform these functions themselves for their own satellites. NASA provides launches and launch services for all corporations under reimbursable contract arrangements.

Technology

Most communications satellites are placed in geostationary satellite orbit (GSO), a circular orbit the center of which coincides with the Earth's center, and which lies in the plane of the Earth's Equator. It has a radius of some 42,200 km, which corresponds to an altitude of some 35,800 km above the Equator. On the GSO, a satellite moves around the polar axis with the same period and in the same sense as does the Earth: as a result, the satellite, if visible, would appear from the Earth to be stationed at a fixed point in the sky.

Because its celestial latitude is fixed at 0°, a GSO satellite's position is defined by its longitude.

The definition of the GSO given above is theoretical because several natural forces perturb the orbit of the spacecraft. A satellite placed in GSO and then left unattended will suffer changes both in its longitude and in its latitude, Seen from the ground, these changes become alterations in the elevation and azimuth angle of the satellite. In order to keep the satellite in GSO, it is necessary to resort to artificial, "stationkeeping devices. " At present, stationkeeping is considered adequately accurate if the satellite is maintained within a range of &/–O. 10 in both longitude and latitude. Because of the remaining motions of the satellite, GSO is not actually a circle, but rather a narrow torus with dimensions corresponding to some 150 km of north-south variation and 30 km of altitude variation.

GSO belongs to a broader family of orbits called geosynchronous; these orbits are generally inclined with respect to the equatorial plane, they may be circular or elliptical, but satellites move on them with the same period, and with the same sense of rotation, as the Earth. Geosynchronous satellites are seen from the ground to describe figures of 24-hour periods and varying shapes.[1]

Commercial communications satellites (except for some early U.S. experiments and some developed by the U .S. S. R.) lie in GSO. The reason for this choice is that advantages of GSO far outweigh its disadvantages. The advantages are as follows:[2]

- The satellite remains essentially stationary relative to look angle of the Earth station antennas; the cost of computer-controlled tracking of the satellite can be avoided. A fixed antenna (with provision for manual adjustment) will suffice.
- There is no need to switch from one satellite to another as one disappears over the horizon.
- Because the radius of GSO is so large, a GSO satellite is in line-of-sight from 42.4 percent of the Earth's surface (or 38 percent, if angles of elevation below 50 are not used). A large number of Earth stations may thus intercommunicate.
- Three communications satellites can provide coverage of 90 percent of the globe; only the polar regions cannot be reached.

The disadvantages of GSO satellites are:[3]

- Latitudes greater than 81 .25° north and south (or 77o, if angles of elevation below 5° are excluded) are not covered.
- Because of the distance of the satellite, the received signal power, which diminishes inversely as the square of the distance, is weak, and the signal propagation delay is 270 milliseconds. To minimize the effects of this time delay and the associated effects of echo, which are problems both in voice conversations and in error correction equipment used with high-speed data circuits, echo suppressors and echo chancellors have been developed.

For a given position of GSO, there is a definite area on the surface of the Earth within which all points can effectively intercommunicate with a satellite in that given position, the so-called service zone. In order to cover a maximal service zone, positions for the satellite are severely limited. Satellites intended for intercontinental, or generally, global service must by necessity have priority for certain orbital longitude slots, once the service zone has been defined. (This comment applies not only to telecommunication services, but also to the observation zone in cases of meteorological or Earth observation missions.) On the other hand, satellites that service or observe a relatively small area of the Earth's surface can generally be positioned with greater flexibility, the more so the lower the mean latitude of the served areas. However, small service areas that extend to higher latitudes will also be limited in their satellite positions because of the limited visibility of the GSO from high latitudes.

As a result of these various constraints imposed on the positions of GSO satellites, with radiofrequency constraints not yet considered, the GSO is not, and probably will never be, populated with

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[1] International Aeronautical Federation, ' 'On the Efficient Use of the Geostationary Orbit, " 1980, p. 8.

[2] James Martin, *Communications Satellites*, p. 45.

Ibid., p. 45.

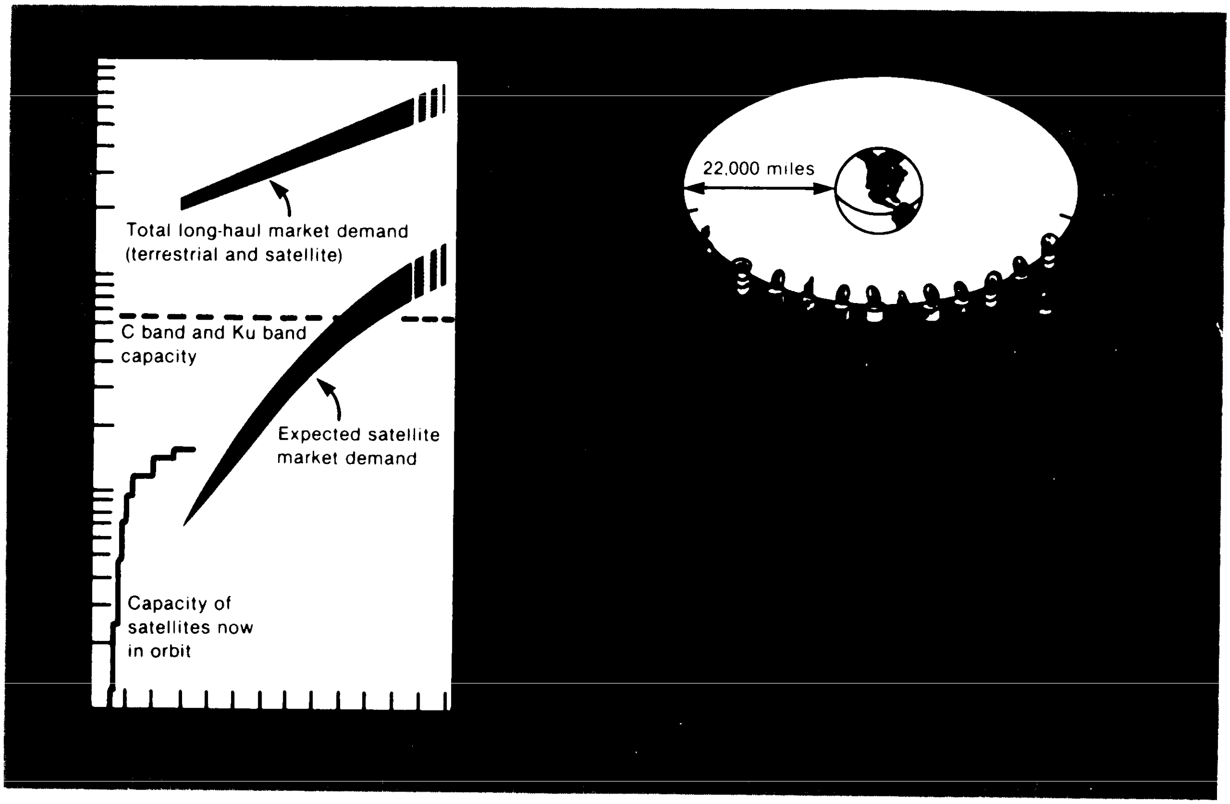
a uniform density of satellites. [t follows that congestion in desirable arcs of the GSO will proceed more rapidly as demand for service grows than was initially envisioned by the regulatory agencies (fig. 1).

Radiofrequency allocations and GSO positions are controlled by the International Telecommunications Union (ITU). ITU is responsible for the maintenance of international cooperation in communications and it assigns operating frequencies and GSO slots to satellite communications systems.

With the early satellites, the enormous distances involved, the limited channel capacity, and the limited power available to the transponders–transmitter-and-receiver pairs on the spacecraft-dictated that Earth stations use powerful transmitters, very large antennas, and sensitive receivers. Those requirements generally still hold true, but contemporary commercial communications satellites carry a dozen or more transponders, each capable of relaying as many as 600 voice channels. Wide-band signals are beamed to the satellite from an Earth station on an assigned up-link (Earth-to-space) frequency; the satellite receives the signals and retransmits them on a down-link (space-to-Earth) frequency to an Earth station that may be thousands of kilometers away from the transmitting Earth station. By convention, to describe the band used by a particular satellite, the up-link frequency is given, followed by the down-link frequency (e.g., 6/4 GHz).

Satellites must be sufficiently separated to avoid radio interference. The required separation between satellites depends on several factors, including the beamwidths of satellite and Earth-station antennas, the side-lobe performance of Earth-station antennas, the modulation technique employed, and the carrier frequency of the trans-

figure 1 .—The Communications Problem



SOURCE: National Aeronautics and Space Administration.

missions. Currently, a 30 separation of spacecraft operating in the 6/4 GHz band is required. In any case, only a limited number of spacecraft can be accommodated in a given arc of geostationary orbit.

Current commercial communications satellites operate primarily in two bands of the microwave region of the radio spectrum, the 6/4 and the 14/1 2 GHz bands (or, the C and the Ku bands, respectively), well above the band used for ultra high frequency (UHF) television broadcasting. At these frequencies, signals are propagated in straight lines, requiring the satellite to be within line-of-sight of Earth stations. The very narrow beam widths require that the ground and satellite antennas be alined precisely, within a fraction of a minute of arc.

As use of the 14/12 band is still in its early stages, nearly all commercially operated communications satellites operate in the 6/4 band. Because this band is shared with heavily congested microwave relay systems, collocating an Earth station poses the problem of finding an interference-free location. There are few such locations around large population centers, which have the greatest need for communications services. Moreover, relatively large antennas and costly Earth stations are required to provide high-density telephone-type traffic. Once the allocated band is filled, further increases in satellite capacity can be achieved only by reuse of the available frequency spectrum. Reuse is possible both by reducing the down-link beam width and by increasing the satellite antenna gain so that different beams cover different service areas.

Capacity can be further increased by polarization diversity. A vertically polarized beam can be transmitted along with a horizontally polarized beam of the same frequency, and the two can be detected and received separately. Polarization diversity occurs when two beams with identical or overlapping frequency bands are orthogonally polarized. Receivers are designed to respond to only one polarization, so that the same frequency band can be used twice within the same coverage area—i.e., using two polarized beams in the same frequency range doubles the amount of information that can be sent with that bandwidth.

From 1980 to 1990, increasing demand for North American satellite circuits will outstrip the available capacity of the geostationary orbit for 6/4 GHz systems, even with the application of frequency reuse techniques. In addition, the difficulty of locating Earth stations in and near the communication sources in population centers will accelerate the use of the higher frequency bands. To meet these projected demands, additional satellites will become operational in the 14/1 2 GHz bands. Because there is no sharing of these frequencies in the United States with the terrestrial radio relay service, Earth stations could be located directly in cities. Recent research (the CTS experiment) has indicated that 3-m ground antennas are adequate for J 4/12 reception. Techniques such as increased satellite transmitter power, higher antenna gain, and spot beam spacecraft antennas must compensate for this use of smaller ground antennas and the occasional rain attenuation in the higher frequency bands (discussed below). A disadvantage of spot beam antennas is that the area they can serve is reduced. Thus, multiple spot beams must be provided, and satellite transmitter power increased to cover the same total area as before.

A constraint on operations in the 14/12 GHz band is that signals transmitted from the satellite to Earth can suffer significant attenuation during periods of intense rainfall (a problem that will be worse at 30/20 GHz, the Ka band). Measurements and analysis.have been made of the effects of this attenuation on satellite signal propagation. Satellite systems using this band must have high power levels (a factor that increases their cost), rely on paired Earth stations geographically separated (“diversity”), or have some other form of backup, if all ground locations require that service be available nearly 100 percent of the time. However, for many commercial applications, rain outages can be tolerated.

An important factor in satellite communication in the 1980’s will be the use of the space shuttle for many launches. The shuttle will facilitate the introduction of physically larger, more powerful satellites with increased capabilities. However, to achieve synchronous orbit, expendable rockets to boost payloads from low-Earth orbit (LEO) will also be needed. In addition, so-called large plat-

forms may be assembled in LEO, where their components have been transported on two or more shuttle flights, and then raised to GSO with an expendable upper stage. Frequency reuse techniques will be common on next generation satellites, providing a further significant increase in total available capacity. Future satellites will also have increased sensitivity in up-link reception, increased effective down-link power, and reduced susceptibility to interference from signals associated with adjacent satellites in geostationary orbit.

Except for AT&T's LEO TELSTAR, flown in 1962, the basic research, development, and demonstration (RD&D) establishing the practicality of satellite communications was done by NASA, with substantial industrial involvement. RD&D for direct broadcast satellites, including early attempts to develop market constituencies, was also done by NASA. From 1973, when its satellite communications research and development (R&D) activities were curtailed on the assumption that the private sector would continue the R&D, until 1980, NASA did not pursue such activities vigorously except for completing the direct broadcast satellite programs of ATS-6 and, in conjunction with the Canadians, CTS.

New Programs

In 1980, because of growing concern over the perceived loss of a technological lead in communications satellites, NASA reactivated its R&D program at 30/20 GHz. This work is directed toward wideband transponder capability intended to explore the allocated but unoccupied bands at 30/20 GHz. Technologies under development include onboard switching, solid state transmitters, switched, multiple-beam antennas, and low-noise receivers for satellite use. NASA hopes to demonstrate the new band technologies in orbit on a new satellite, to be developed for a 1986 launch. The system concept is based on traffic projections developed for NASA by two

Photo credit: National Aeronautics and Space Administration

Satellite frequencies

satellite communications carriers, COMSAT and American Satellite Co. NASA is also developing adaptive, multibeam antenna technology at L-band, the band in use for maritime (and aeronautical) satellite communications use.

While NASA pursues a program currently dominated by R&D at 30/20 GHz, commercial entities are expanding their channel capacities in lower frequency bands at 6/4 GHz and 14/12 GHz. SBS'S launch in the fall of 1980 marks the first U.S. commercial satellite use of the 14/12 GHz band (Ku band). Canada's ANIK-B and-C were the first domestic satellites to exploit that band, predating SBS by 2 years or more. INTELSAT-V, launched in late-l 980, is carrying traffic at both 6/4 and 14/12 GHz. Commercial carriers' plans for future satellites through the 199o's continue to concentrate on these bands, using multiple-beam antenna technologies and the frequency reuse technologies first developed in the late 1970's and continuing in development today. Multiple-beam antenna technologies refer to the use of a single antenna to send and receive more than one frequency signal. Frequency reuse technologies refer to the ability to handle the same frequency in different modes, thereby increasing capacity without increasing spectrum use.

Continuing advances in technology, many of them by industry in the late **1970's** as markets for 12 GHz Earth stations became viable, have made it possible for commercial carriers to provide many of the services initially demonstrated on ATS-6 by NASA under the classification "community broadcasting. " Cable program distribution, interactive services such as multipoint teleconferencing, educational broadcasting, and remote health-care services are now being provided by the commercial carriers. These services, together with the traditional point-to-point services, are carried on first generation satellites operating at 6/4 GHz.

Advances in bandwidth compression and frequency reuse technologies appear, for perhaps the next decade, to allow first generation satellites to keep pace with traffic projections. Second generation satellites such an INTELSAT-V and Advanced WESTAR, which will start flying in the nexts years, include increased capacity sufficient to accommodate traffic projections by using new technologies such as switchable, multiple-beam antennas, onboard switching and signal processing, and frequency reuse capabilities at frequencies of 6/4, 14/1 1, and 14/12 GHz. These will require developing large, possibly deployable space structures, distributed, solid state transmitters and low-noise receivers, precise and possibly adaptive phase control, and attitude stabilization in the presence of solar-array or antenna-structure motions.

Except for the 9-m deployable antenna of NASA's ATS-6, DOD (on the Defense Satellite Communications System, Phase III) and the commercial sector (I NTELSAT-V, Advanced WESTAR) have the lead in multiple, switched-beam antennas and in somewhat larger, deployable antenna structures. ATS-6 included, these spacecraft types are the first so-called orbiting antenna farms, carrying capability for multiband, multibeam communications services. As future traffic projections indicate a limitation of capacity, plans for the first satellite generation of the 1990's could be expected to include 30/20 GHz frequencies in addition to 6/4, 14/1 1, and 14/12 GHz. The trend will be toward fewer, larger satellites carrying more bands, more beams, and more diverse services. These satellites will incorporate some of the space construction techniques developed during the 1980's.

Commercial sector hardware is provided by industrial firms, many of them Japanese, French, German, and Italian. As part of its reactivated program, NASA will conduct R&D in advanced technologies for low-cost Earth stations. The results of this R&D, which also involves industrial firms, are intended for transfer to the private sector. NASA's customary applications experiment-demonstration activities with its ATS satellite series have been transferred to the National Telecommunications and Information Administration (NTIA) in the Department of Commerce, together with responsibility for stimulating new applications experiments and demonstrations and for aggregating future markets.

Tracking and Data Relay Satellite System

Advanced WESTAR is a variation of the Tracking and Data Relay Satellite System (TDRSS) being leased by NASA from Space Communications Co. TDRSS comprises two satellites in synchronous orbit, controlled from a master station at White Sands, N. Mex., and used to track and relay data from LEO satellites to the ground. it will replace much of NASA's terrestrial Space Tracking and Data Network (STDN) and will increase the potential for continuous coverage of other, LEO satellites. For the lowest-altitude orbits, coverage will increase from about 15 to 85 percent, providing a great improvement in timely data acquisition for NASA experimental and NOAA operations. This capability will greatly reduce the need for costly and unreliable satellite data recorders. While Advanced WESTAR carries 6/4, 14/11, and 14/1 2 GHz capability, TDRSS also carries capability in the space research bands at 1.7/1 .8, and 2.0/2.3 GHz. Both spacecraft use the same basic structure, including deployable antennas for some of the three or four bands they carry. The first TDRSS launch is planned for the shuttle in early 1983, the second 6 months later. Two Advanced WESTARs will be launched in 1984; one will be dedicated to commercial service and the other will serve as a shared spare between NASA and Space Communications Co.

Navigation

Most of the U.S. work on navigation has been done by DOD. The Navy navigation satellite system transmissions have been made available to the public for the cost of the receiver and position-fixing computer equipment. Position can be fixed to an accuracy of 50 ft if processing time is long enough (up to 12 hours). Such performance is suitable for ships but not for aircraft, whose positions change too rapidly.

Work by NASA and the European Space Research Organization in 1969-70 had defined a system (Aerosat) that could work for aircraft. Capable of handling 500 aircraft simultaneously, it was also of interest for air traffic control. Responsibility for Aerosat was transferred to the Federal Aviation Administration (FAA) early in 1971. in 1973, work on it was terminated.

NASA has continued to pursue studies in search and rescue, but not in navigation or traffic control, based on special receivers attached to NOAA meteorological satellites to detect signals of distress beacons carried by aircraft and ships. NASA is pursuing this experimental work cooperatively with DOD, the Department of Transportation, and with Canada, France, and the U.S.S.R. The United States is providing the spacecraft, launch vehicles, and the U.S. ground stations; Canada is providing the space telecommunications equipment and ground station in their country; and, France is providing an onboard processor and receiver. The Soviet Union will launch and maintain in orbit two spacecraft operationally compatible with the U. S., Canadian, and French system and will operate their own ground station. in addition to NASA, DOD, and the Department of Transportation are expected to purchase and operate ground stations and participate in the program test and evaluation phase while NOAA is providing the spacecraft for modification.

Satellite Remote Sensing

Remote sensing from satellites is one important component of the general field of detecting, recognizing, and evaluating objects from a distance by means of advanced electro-optical instruments with cybernetic interpretation. Radar, sonar, astronomical and aerial photography are all forms of remote sensing. Satellite remote sensing is used in conjunction with aerial photography and aerial radar scanning to assess and help to control the productivity of the surface of the Earth, to help locate subsurface resources, and to understand, forecast, and, eventually, help control the environment.

Satellite remote sensing will be discussed in this section under the following three categories: 1) ocean sensing; 2) Earth resources sensing; and 3) environmental sensing. Listed in this order, they lead from an area with no current operational systems to an area that has had operational space systems for 14 years.

Ocean Sensing

This is the newest, least developed of satellite remote-sensing efforts. NASA, NOAA, DOD and the oceanographic science community all recognize the tremendous potential that satellites have for the study of the world's oceans. Gathering ocean data from satellites may be the only reasonable way to observe ocean processes routinely and continuously. Currently, there are no existing or planned U.S. civilian operational ocean-sensing satellite systems.

NASA's SEASAT, which was flown in 1978 and failed prematurely after 6 months, was a satellite demonstration to show what an operational ocean-sensing system could do. Each of SEASAT's complement of sensors had been flown before but never together on a civilian, ocean-oriented spacecraft.

Along with SEASAT, NIMBUS, and the Geodynamic Experimental Ocean Satellite (GEOS) data have been used in ocean studies. NIMBUS is classed as an experimental weather/climate spacecraft; GEOS was primarily to study ocean waves. The data these satellites supply consist primarily of global wind fields, sea states, surface temperature, ice coverage, and ocean color.

SEASAT data have demonstrated that scatterometer observations enable space mapping of the detailed structure of the ocean surface wind fields, including atmospheric fronts and typhoons. Altimeter observations enable mapping of surface waves and circulation features such as the Gulf Stream and mesoscale eddies. Microwave radiometer observations enable mapping of the characteristics of sea ice. Color scanner observations enable mapping of chlorophyll concentration. Taken collectively, these observations will help enable the determination of the general circulation of the ocean—both the wind-driven and geostrophic components—along with sea ice coverage and primary biological productivity in the oceans.

Applications of ocean sensing divide into two classes—operational and scientific. NOAA uses the data from the experiments to support its operational responsibilities that include: the management and conservation of marine resources; the preservation, conservation, and development of U.S. coastal resources; the prediction of weather; and, the provision of maps, charts, surveys, and other specialized data for navigation. Ocean sensing from space is expected to contribute to safety, to improve the efficiency of weather forecasting, and to reduce the cost of shipping operations, air transportation, offshore oil and gas exploration and drilling, platform operations, marine construction, commercial fishing, pollution monitoring, ice monitoring, and marine search and rescue.

NASA, in conjunction with academia, will use the data primarily for R&D in weather and climate. NASA also will increase its participation with the oceanographic community by supporting university scientists and encouraging further commercial participation in carrying out a number of advanced studies for future research missions in applying satellite remote sensing to oceanography.

NASA's ocean research programs will include processing SEASAT data records into final geophysical units and their subsequent analysis; evaluation of the performance of X/L/C-band aircraft synthetic aperture radar (SAR) in conjunction with experiments undertaken by the National Science Foundation (NSF) on warm Gulf Stream rings and coastal ocean dynamics; characterization of sea ice properties by various remote-sensing techniques; definition of altimetry dependence on sea state; investigation of photoplankton productivity associated with physical and chemical ocean properties near the Nantucket Shoals, in cooperation with the National Marine Fisheries Service; refinement of techniques for assimilation of wind data from the scatterometer into numerical models; and development of a shipborne lidar system for basic studies of optical oceanography. The ocean processes program will develop techniques for assimilating satellite data–especially scatterometer wind data—into numerical models, and demonstrate a remote-sensing system that will supply specific global oceanographic data on a routine and repetitive basis to meet specific user needs.

Earth Resources Sensing

The U.S. program addresses the needs for gathering the vital information required for managing the world's limited food, water, energy supplies, and mineral resources, and for identifying potential geodetic (primarily earthquake) hazards. Its objective is to develop and demonstrate the use of space technology for providing the United States with a global capability for monitoring and forecasting major agricultural commodities, managing water resources, assessing land use, improving the exploration for mineral and energy resources, and understanding the dynamic characteristics of the Earth's crust. Many, if not most, Federal agencies use space data in the day-to-day conduct of their missions (see fig. 2).

Numerous State and local governments, many in conjunction with academia, use satellite data for a whole range of projects, including land cover classification, wetland development, and water management (see tables 7 and 8). The universities are studying ways to manipulate the data and apply them to a variety of problems. Industry has made some use of space-generated data, especially in its search for nonrenewable resources. Several companies that are characterized as "value-added" firms take the raw satellite data, manipulate it, integrate it with other data and sell the information products to a variety of users.

Currently there are no plans for a Federal operational Earth resources-sensing satellite system. NOAA will shortly (1983) assume operation of NASA's experimental Landsat system, but there are no plans for the Government to continue to operate a satellite land remote-sensing system once Landsat fails. NASA's principal activities include pursuing the R&D necessary for developing and improving space remote-sensing capabilities and the related information extraction techniques, providing for the acquisition of space data, and joint research, development, and test projects with users. Its goal is to establish the routine use of global data collection systems. American industry has been the dominant source of equipment, provided largely under Government funding, for the U.S. remote-sensing effort. It has supplied spacecraft, sensing instruments, Earth stations, data processing equipment, and information extraction devices.

Landsat Technology

Space Segment

The return beam vidicon (RBV), a kind of television camera, was initally promoted for use in Landsat by the Department of the Interior. The RBV uses a shutter to expose a light-sensitive plate and then scans the plate with an electron beam to capture the image on videotape or to radio it to the ground. Although Landsat 3 carries only two RBVS, three of these devices would allow the reconstruction of color pictures. Each RBV image from Landsat 3 covers an area 90 km on a side (180 km total swath) and has an equivalent instantaneous field of view (IFOV) of 40 m. The low distortion of the RBV makes its especially useful for mapmaking.

The multispectral scanner (MSS) uses a mirror to scan the scene on the ground one line at a time, reflecting the light onto a series of detectors (photoelectric cells) sensitive to four different spectral regions. MSS scans a swath 185 km wide and has an IFOV of 80 m, which for many scenes is approximately equivalent to a photographic resolution of about 160 m. MSS provides better spectral resolution, but higher distortion, than does RBV. It was therefore championed by the Department of Agriculture (USDA) as particularly useful for monitoring crops.

The thematic mapper (TM) is a remote sensor with seven spectral bands covering the visible, near-infrared, and thermal infrared regions of the spectrum (see fig. 3). It is now scheduled for launch in the third quarter of 1982 aboard Landsat D, from which it will achieve complete coverage of the Earth's surface every 16 days.

The TM is designed to satisfy more demanding performance specifications than have previously been applied to an instrument of its type. In response to these requirements, the design incorporates advanced state-of-the-technology materials, structures, control techniques, calibration mechanisms, data handling, and electronics. De-

Figure 2.—Earth Resources Sensing

The top photograph shows upper Delaware, Maryland, and the Virgina peninsula taken from the Landsat 1 satellite at an altitude of 568 miles. The photo at bottom left shows a technician performing a quality control assessment of the Landsat 1 photo while on the bottom right, a technician prepared a negative of the Landsat 1 photo for printing in the Goddard Space Flight Center processing facility.

Table 7.—Overview of Landsat Applications in the 50 States

State	Water resources	Forestry/ rangeland	Wildlife management	Land resources management	Environmental management	Agriculture	Geologic mapping
Alabama	X	X		x	x		X
Alaska	X		x	x	x		X
Arizona	X	X	X	x	x	x	X
Arkansas				X		X	X
California	X	X	X	X	X	X	X
Colorado	X		X	x	x	X	
Connecticut							
Delaware	X				X		X
Florida	X	X	X	X	X	X	
Georgia	X	X	X	X	X	X	X
Hawaii		X		X	X		
Idaho	X	X	X	X		X	
Illinois	X	X		X	X	X	
Indiana		X	X	X	x	x	x
Iowa	X			x	x	x	X
Kansas	X		X	X		X	X
Kentucky	x	X	X	X	X	X	X
Louisiana	X	X		X	X	X	
Maine	X	X		X	X	X	
Maryland				X	X	X	X
Massachusetts					X		
Michigan				X	X		
Minnesota	X	X	X	X	X	X	X
Mississippi	X	X	X	X	X	X	
Missouri	X	X	X	X	X	X	X
Montana	X	X		X		X	
Nebraska	x	X	X	x	x	x	x
Nevada	X						
New Hampshire		X		X			
New Jersey		X		X	X		
New Mexico		X	X	X	X	X	
New York	X	X	X		X	X	X
North Carolina	X	X	X	x	X	X	
North Dakota	x		X	X	X	X	
Ohio				X			X
Oklahoma	X	X		X	X	X	X
Oregon	X	X	X	X	X	X	
Pennsylvania		X		X	X		X
Rhode Island							
South Carolina	x	x	x	X	x		
South Dakota	x	X	x	x	x	X	x
Tennessee			x	x	x		X
Texas	x	X	X	X	X	X	x
Utah		X	X		X		X
Vermont		X			X		
Virginia	x	X		X	X	X	X
Washington	x	X	X	X	X		
West Virginia		X			X		X
Wisconsin	x	X		X	X	X	
Wyoming	X		X	X	X	X	x

SOURCE: National Governors Conference,

Table 8.—Summary of Operational Landsat Applications in the States[a]

A. **Water Resources Management**

Surface water inventory (7)
Flood control mapping and damage assessment (7)
Snow cover mapping (3)
Water resources planning and management (2)
Irrigation demand estimation (2)
Determination of runoff from cropland (2)
Watershed or basin studies
Water circulation
Lake eutrophication survey
Irrigation/saline soil
Geothermal potential analysis
Ground water location
Offshore ice studies

B. **Forestry and Rangeland Management**

Forest inventory (6)
Forest productivity assessment (3)
Clear cut assessment (2)
Forest habitat assessment (2)
Wildlife range assessment (2)
Fire fuel potential
Fire damage assessment and recovery

C. **Fish and Wildlife Management**

Wildlife habitat inventory (9)
Wetlands location and analysis (3)
Vegetation classification
Snow pack mapping
Salt exposure

D, **Land Resources Management**

Land cover inventory (18)
Comprehensive planning (4)
Corridor analysis (2)
Facility siting (2)
Flood plain delineation
Solid waste management
Lake shore management

E. Environmental Management

Water quality assessment and planning (16)
Environmental analysis or impact assessment (4)
Coastal zone management (3)
Surface mine inventory and monitoring (2)
Wetlands mapping
Lake water quality
Shoreline delineation
Oil and gas lease sales
Resource inventory
Dredge and fill permits
Marsh salinization

F. Agriculture

Crop inventory (7)
Irrigated crop inventory (5)
Noxious weeds assessment
Crop yield prediction
Grove surveys
Assessment of flood damage
Disease monitoring

G. Geological Mapping

Lineament mapping (9)
Geological mapping (6)
Mineral surveys (4)
Powerplant siting
Radioactive waste storage

[a] The number in ( ) indicates the number of States for each application, where greater than 1.

SOURCE: National Governors Conference

velopment and fabrication of the TM are proceeding on schedule. Most of the subsystem parameters which have been tested so far have met or exceeded specifications.

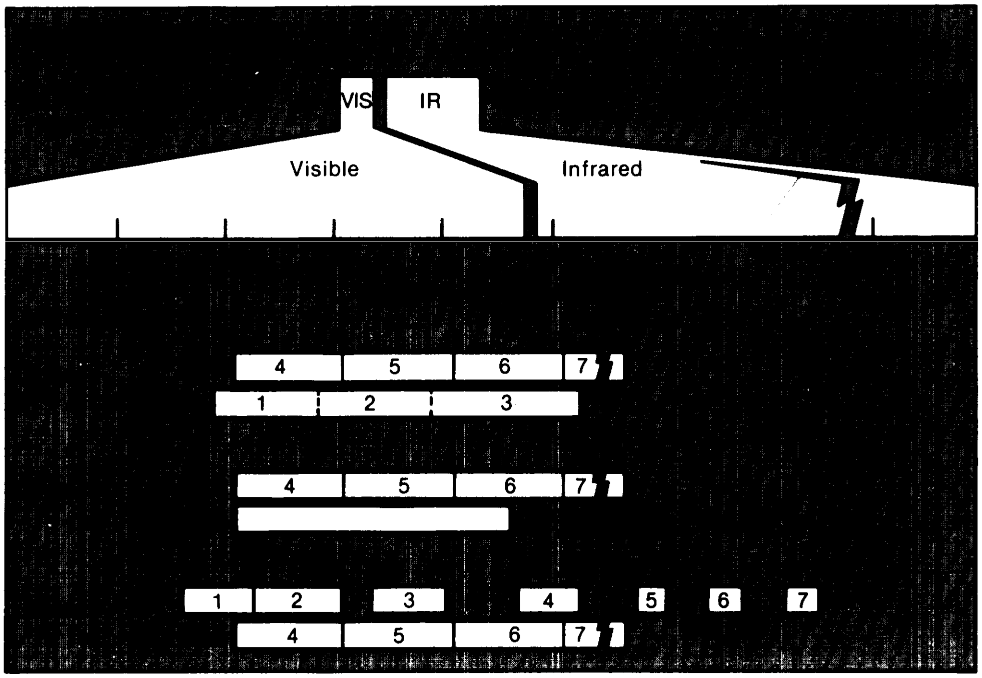
Ground Segment

Data can be transmitted to Earth when the satellite is within view of one of the receiving stations (fig. 4)—the NASA stations in Alaska, California, and Maryland, and nine foreign-owned and -operated stations that function under agreements with NASA. Data acquired while the spacecraft is beyond the range of a ground station are stored by an onboard, wide-band video tape recorder until it is within range of a U.S. station. The rate of data transmission from satellite to ground station is on the order of megabits/second.

A control center at the Goddard Space Flight Center (Goddard) monitors and commands the satellite to acquire and transmit data directly to U.S. or foreign ground stations.

The master recordings (station tapes) received at U.S. ground stations of Landsat 3 are sent to Goddard for preprocessing. This initial step in data reduction consists of segregating data from each of the spectral bands and applying two sorts of corrections: a) radiometric corrections to account for the difference in response of the detectors in the various spectral bands, and b) geomet-

Figure 3.—Landsat Bands and Electromagnetic Spectrum Comparison



aThematic mapper.

SOURCE: U.S. Geological Survey,

ric corrections that account for distortions in the satellite viewing process and relate the received data to the exact position on the ground that was observed by the satellite. The results of this preprocessing are recorded in the form of high-density digital tape (H DDT), either as fully corrected data, or with the required geometric corrections only noted on the tape. Foreign ground stations perform an equivalent function, although not all of them apply a full set of corrections.

HDDTs are provided to the Department of the Interior's EROS Data Center in Sioux Falls, S. Dak., and the USDA facility in Houston, Tex. At the EROS Data Center, the data in HDDT form are put through additional computer processes to convert them into standard data products suitable for sale to public or private sector customers. They, in turn, may use these products in that form or further process them for their own use or for resale to additional customers.

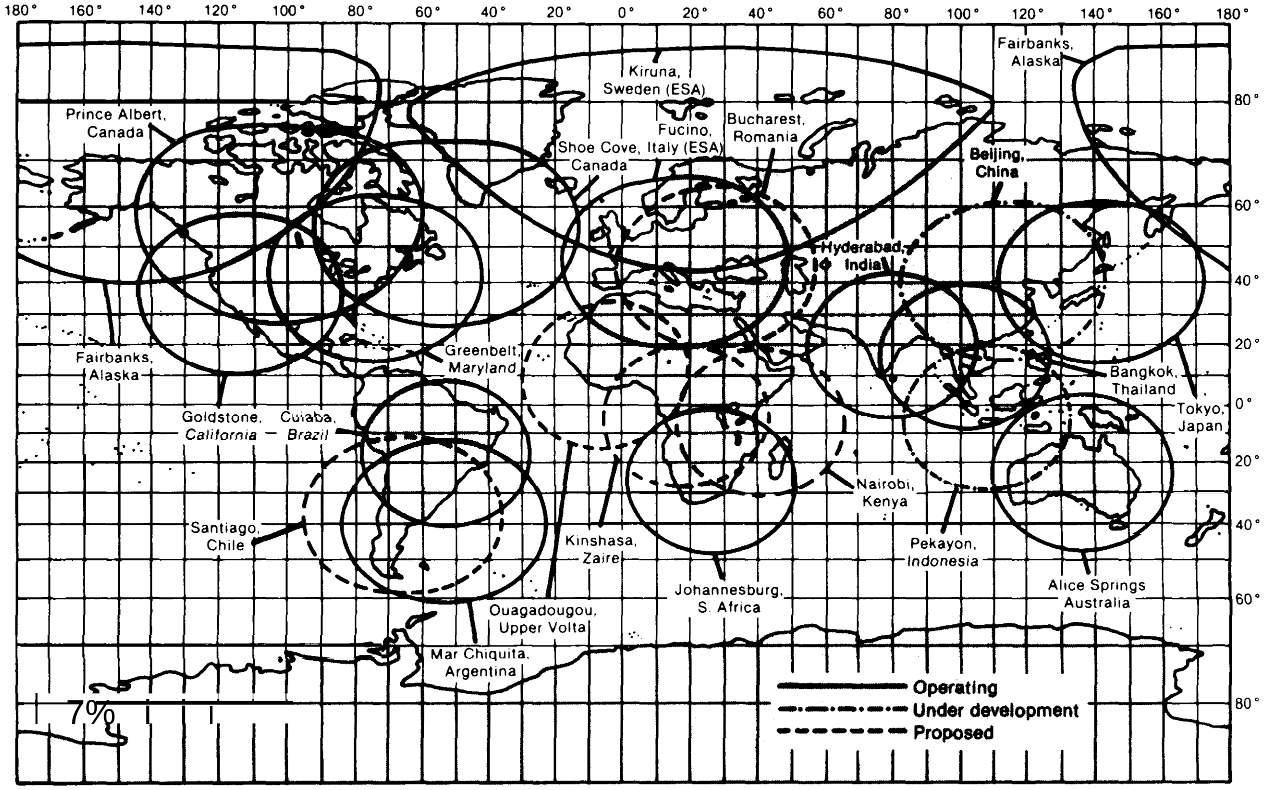
Two classes of standard data products are available: film imagery, which is convenient for those accustomed to working with maps and photographs, and computer compatible tapes (CCTS). The tape form is suitable for input to standard computers and lends itself to automated or specialized data handling and analysis. The digital form of CCTS makes them especially appropriate for integration with other digital data.

For most uses, the data as they emerge from preprocessing at Goddard and processing at EROS are still in raw form. It is at this point that firms in the private sector step in to process Landsat data further. Such firms constitute the value-added industry. Value-added firms are found both in the United States and abroad; most of them are small. The kinds of work they perform are: image processing, image enhancement, image interpretation, and integration of Landsat data with data from other sources.

Other Remote-Sensing Programs

Currently Federal experimental or scientific flight programs include the Landsat series, Magsat, and the Heat Capacity Mapping Mission (HCMM). Landsat 3 is aging but continues to be

Figure 4.—Current and Probable Landsat Ground Stations



NOTE: Coverage circles based on Landsat-3 reception (altitude: 917 km)

SOURCE: National Aeronautics and Space Administration.

the **primary** source of Earth resources data. **Landsat** D will soon be launched, and if plans to launch the follow-on satellite, Landsat D', come to fruition, both are expected to operate until the mid- to late-1980's. New sensor capabilities on Landsats D and D' are expected to be especially useful for nonrenewable resources observations. Magsat, launched in 1979, has charted the Earth's magnetic fields to aid in navigation and to provide a better understanding of the solid Earth for geophysical and geologic studies; and, the HCMM has made global measurements of Earth surface temperature variation to aid in locating mineral resources and in measuring water runoff from snowmelt. NASA is also planning to fly experiments on early space shuttle missions designed to test the applicability of active microwave measurements, and of high-resolution imagery for mapping investigations. It is also studying how to define the appropriate space systems for gravity measurements for solid Earth studies, for global stereoscopic imagery for resource exploration, and for improved remote sensors for multiple applications.

NASA has also entered into joint R&D activities with other Federal agencies (USDA, USDC, USAID) to advance the understanding of how to apply multiple data sources in improving agricultural early warning and crop commodity forecasting (AgRISTARS). The AgRISTARS program has been somewhat restructured by lengthening the schedules and changing the program scope in several areas. This restructuring has been caused by constraints on the fiscal year 1982 budgets of the involved agencies and the delay in the availability of Landsat D. Other joint research activities are planned with additional Federal agencies and with international organizations for advancing the scientific knowledge of the solid Earth.

ENVIRONMENTAL SENSING

understanding the dynamics and limitations of our environment is essential to our long-term survival and important to many day-to-day activities. The global interrelationships between the atmosphere, ocean, land, and space environments can be studied only from space. These programs are aided by data from the ocean and Earth resources sensing systems.

The operational meteorological satellite systems of NOAA (GOES and TIROS) form the backbone of the environmental program. Prediction of the weather, monitoring and control of pollution, ship routing, storm warning, and modeling of long-term trends in climate and the stratosphere are all areas of study.

NOAA's operational responsibility regarding weather and climate is to monitor the weather and prepare weather forecasts for a myriad of users. NOAA, therefore, has the responsibility for the ground-based observation systems, the operational meteorological satellite system, and the related receiving , analyzing, and disseminating systems that turn the space and ground data into weather forecasts. For the space segment, NOAA coordinates with NASA for the improvement of the space and space-tied systems and for the procurement of spacecraft and launch arrangements. NOAA is also charged with conducting R&D in the analysis and application of satellite data.

The primary and routine use of the satellite data from the NOAA system is, of course, weather predicting. NOAA transforms them into a broad variety of weather projections and distributes them throughout the world. In addition to being used in real-time weather predicting operations, they are also placed in archives for future theoretical research and case studies. These data are widely used by meteorologists and environmental scientists in Government and academia in routine operations throughout the world and are considered indispensable for conducting atmospheric analyses and preparing short-range weather forecasts.

Users of weather data vary in their involvement with determining the standard weather forecasting services provided by NOAA. Aviators in well-established working groups provide regular data on their needs through FAA. However, only about one-third of the farming sector is well-served by standard NOAA products. Private weather services provide specialized forecasting to many users whose requirements are not met by those products.

NASA studies and flight missions are directed at all characteristics of the atmosphere, including upper atmospheric and tropospheric air quality, global weather, severe storms, oceanic processes, and general climate.

NASA launched three atmospheric research/demonstration satellites in the late 1970's, SEASAT, NIMBUS-7, and Stratospheric Aerosol and Gas Experiment (SAGE). As noted above, SEASAT has ceased to function, but returned significant ocean data, which are being studied. NIMBUS-7 and SAGE are performing satisfactorily. SAGE primarily measures atmospheric concentrations of ozone and aerosols in an attempt to show how pollutants might be transported globally. NASA has planned to launch the Halogen Occultation Experiment (HALOE) and the Earth Radiation Budget Experiments (ERBE) spacecraft in the mid-l 980's. HALOE will measure global atmospheric profiles of key species involved in the depletion of stratospheric ozone. ERBE is to measure the radiation balance over the globe to gain basic insights into the reasons for climatic fluctuations. NASA's advanced planning includes the uses of satellites for the simultaneous global study of the radiative, chemical, and dynamic processes occurring in the upper atmosphere.

It is apparent that air pollution problems must be solved on a regional basis, and that global chemical budgets (e.g., carbon dioxide) act both as tracers of transport processes and as a background for regional events. NASA, the Environmental Protection Agency (EPA), and NSF are focusing on these areas with field analytical and laboratory studies to quantify the global carbon-nitrogen-ozone and sulfur-ammonia-aerosol chemical systems. Data derived from spacecraft are essential to these efforts.

Severe storms, tornados, damaging downdrafts, and destructive lightning are being studied by NOAA and NASA to improve observation and forecasting of such events. Remotely sensed data from NASA's severe environmental storms and mesoscale experiment, and ongoing mesoscale modeling efforts for forecast improvement with computer interactive systems will lead to a joint NASA/NOAA project at NOAA's National Severe Storm Forecast Center, similar to the recently successful frost-freeze warning demonstration in Florida. Improved airborne wind measurement tools and temperature and moisture sounders on the GOES-D spacecraft are being evaluated.

International Weather Activities

WORLD METEOROLOGICAL ORGANIZATION (WMO)

The United States participates in international meteorological programs through WMO, a specialized agency of the United Nations that was established in 1951. It was formed in order to establish, coordinate, and improve meteorological services throughout the world, U.S. operational and experimental meteorological satellites contribute to this effort. WMO members obtain access to meteorological information from U.S. weather satellites indirectly through a WMO network of international, regional, and national meteorological centers, and directly from automatic picture transmission (APT) receiving sets.

GLOBAL ATMOSPHERIC RESEARCH PROGRAM (GARP)

As part of the U.S. worldwide weather R&D activities, NOAA, NSF, and NASA participate through the National Research Council in GARP. GARP's goal is to conduct studies to understand the atmosphere, It is sponsored by WMO and the International Council of Scientific Unions, with participation and funding provided by all member nations. Current U.S. activities for GARP are directed at analyzing parts of the data from the recently successful GARP global weather experiment, assessing the requirements for improved operational forecasting and defining future remote measurement requirements. This experiment, conducted in 1979, provided a unique set of data that did not exist before. As a result, atmospheric numerical forecast models have been improved and space research is being directed to improved temperature sounders, surface pressure instruments, passive and active microwave moisture sensors, wind sensors, and rainfall measurements technique.

Materials Processing in Space (MPS)

MPS is both a set of new technologies designed to exploit the unique environment of space and a developing program to implement these technologies. The unique properties that make space an ideal environment for processing certain kinds of materials are: 1) the availability of unlimited, unfiltered solar radiation; 2) the existence of a near-perfect vacuum; 3) a range of temperatures, from –200° to +200”F; and, most important, 4) microgravity–an almost complete absence of gravitational force. VVith the exception of long-term microgravity, these properties can be well enough approximated on Earth to allow their extended effects on materials processing to be investigated. The factor of microgravity, however, is what makes MPS so attractive.

Process variables such as temperature, composition, and fluid flow may be controlled far better in an environment of microgravity. As a result, some materials may be manufactured in space with greater precision and fewer defects; others, which cannot be made at all on Earth, may become possible for the first time. MPS looks particularly promising for pharmaceuticals, electronic components, optical equipment, and metal alloys.

Already, a U.S. program to implement these technologies is taking shape. NASA has established an MPS program to pursue the basic science and the applied R&D of microgravity environments. Within NASA's MPS program, a Commercial Applications Office has been set up to encourage the private sector to participate.

EARLY WORK IN SPACE

During the earlier years of the Apollo Program, several unusual phenomena, peculiar to microgravity, were first observed. First considered only as posing problems in the engineering of spacecraft systems, these phenomena were later recognized as clues for inventing processes to manufacture products in space for use on Earth. To broaden the discussion, NASA organized symposia in 1968 and 1969 for industry representatives to discuss the possibilities of MPS. NASA also established in 1969 a new program, "Materials Science and Manufacturing in Space."

Through the early 1970's, in-space research was conducted on Apollo, Skylab, and Apollo-Soyuz missions. Aboard Apollo 14, 16, and 17, several necessarily brief, but important experiments were performed to investigate certain basic processes (i.e., heat flow and convection, electrophoresis, and composite casting). Skylab, the orbiting space laboratory station, allowed for much more extensive experimentation. Altogether, three teams of astronauts conducted 15 MPS experiments. Skylab's materials processing facility, including a multipurpose electric furnace, provided the means of studying more complex processes: crystal growth, metal alloying, eutectics, welding and brazing, fluid effects, and combustion, Again, the 1975 flight of the Apollo-Soyuz test project continued the research conducted on the Apollo and Skylab missions. The processes investigated included: electrophoresis, crystal growth of semiconductors, processing of magnets, convection induced by surface tension, density separation during solidification of two alloys, and halide eutectic growth. Throughout these missions, the experiments performed in space were essentially repetitions of techniques used in terrestrial materials processing.

CONCURRENT WORK ON EARTH

NASA has perfected three terrestrial facilities for attaining microgravity for short periods: drop tubes and drop towers, aircraft flying high-altitude parabolic trajectories, and sounding rockets. These facilities allow relatively low-cost experimentation for MPS investigators to establish and set experimental parameters, to establish proof of concept, and to provide specimens for laboratory research.

Drop tubes and towers allow spacelike microgravity conditions to be achieved for some 2 to 4 seconds. In drop tubes, molten droplets are released into a vertical evacuated tube (either 100 or 300 ft long) and are solidified during free fall. in drop towers, small rockets (used to overcome friction) thrust canisters containing experiment packages down vertical guide rails. These apparatus provide useful opportunities, however fleeting, to study both high-temperature calorimetry and changes in density, surface tension, and volume as liquids solidify.

Although longer in duration by an order of magnitude (1 O to 60 seconds), the microgravity attained by NASA aircraft (KC-132s and F-104Bs) is much less steady than that of drop tubes and towers. The aircraft, therefore, do not provide a suitable environment for precise experimentation, but are useful for training crews and for developing and verifying tests of experiment hardware.

Since introducing the Space Processing Application Rocket (SPAR) Program in 1975, NASA has flown nine sounding rocket missions. These flights provide 4 to 7 minutes of microgravity. However, severe stresses during launch significantly constrain the design of experiments. The SPAR program has resulted in an inventory of low-cost hardware suitable for longer duration experiments during shuttle operations.

FUTURE PLANS

From the foregoing discussion of work already done in space and on Earth, one can see that significant future evolution of MPS experimentation lies in the direction of providing an extended microgravity environment along with more complex hardware. The space shuttle transportation system holds the key to MPS development. Major shuttle facilities for MPS experimentation (small self-contained payloads, the materials experiment assembly, and Spacelab) can be used on shuttle flights lasting up to 1 month,

Small self-contained payloads are packages flown in containers rented by NASA to companies, universities, or private individuals. The payloads, designed by the users, operate under their own power and carry their own recording systems. Some of them may also be used as testbeds for broader experimentation aboard Spacelab.

The materials experiment assembly (MEA), the first article of new materials processing hardware to be flown in the shuttle, is also designed to operate under its own power in its preliminary version. Later models will draw power from the shuttle. Accommodating as many as four experiments

in separately sealed subenclosures, MEA contains a control computer, a heat rejection system, and data recorders.

Spacelab, the centerpiece of NASA's new MPS system, has two **major components, the module and the pallets.** The module provides a habitable laboratory for scientists and engineers to work comfortably in space. The pallets form an open porch in the cargo bay of the orbiter, where instruments may be exposed to space and various experimental apparatus may be accommodated.

Four MPS instruments are currently under development for deployment on Spacelab. The fluid experiment system uses Schlieren photography and holography to study fluid behavior under microgravity. In the vapor crystal growth system, crystals are to be grown from fluids, vapors, or melts of solid materials; the results are recorded by video and holography. The pallet-mounted, acoustic, containerless, positioning module is used to control the position and rotation of a sample to be raised to a temperature of 1,600 degrees by radiant heat. The solidification experiment system employs a modular furnace in which up to 16 samples per flight may be processed. Solidification may be achieved, either under uniform heating and cooling, or directionally, by means of a temperature gradient.

There are several other MPS activities planned for development if funds are approved. There are also important long-term prospects for more advanced activities. These and the various foreign efforts, current or planned, are discussed elsewhere in this assessment.

Space Transportation

Currently the U.S. Government has the sole capability in the United States to launch both manned and unmanned payloads from Earth, Each capability presents different opportunities and different constraints.

MANNED SPACE SYSTEMS

The space transportation system (STS) that has been developed by NASA, with extensive industrial involvement under Government funding, is the sole U.S. system planned to carry humans and objects into space in the 1980's and 1990's. Expendable launch vehicles (ELVS) will continue to provide launch services through the early transition period.

The major components of the STS initially include the reusable space shuttle, upper stages, the remote manipulator system, and the workshop Spacelab. The shuttle will be launched from both the east and west coasts of the United States with a nominal payload capability of 65,000 pounds (29,500 kg) into LEO (185-1,110 km). It can carry a crew of three to seven persons for mission durations up to 30 days.

The space shuttle orbiter, an aircraft-like, reusable spacecraft, will be used to carry payloads to Earth orbit and deploy them from its cargo bay. The remote manipulator system can be attached to the orbiter bay to aid the crew in deploying or retrieving payloads in space, Upper stages will be included with those payloads that must go farther than LEO, i.e., on missions to the planets or to geosynchronous orbit. Spacelab is a complete orbital laboratory that fits into the cargo bay and connects with the crew compartment of the orbiter. It will make possible a variety of human-directed experiments in the space environment. Planned utilization of STS may be seen in table 9 and figure 5.

NASA is conducting numerous studies to provide advanced capabilities for STS:

- Thrust augmentation—a study to supplement the existing shuttle capability with strap-on assist rockets;
- ***Solar electric propulsion systems–solar-***powered ion-engine upper stages for varying orbit and payload requirements;
- ***Orbital transfer*** vehicles–manned and unmanned vehicles capable of moving payloads from the LEO attainable by the shuttle, either to a different LEO or to higher orbits;
- ***Teleoperator maneuvering system–a*** remotely controlled payload maneuvering unit;
- ***Deployable antenna***—an experiment to test the feasibility of deploying very large antennas;
- ***Space*** platforms–shuttle-deployable platforms to perform as test beds for experiments

Table 9.–STS Operations Traffic Model (34 flights through 1985)

	Fiscal year														
	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	Total
Kennedy Space Center:															
NASA	—	3	3	5	7	8	11	12	15	13	15	14	13	12	131
Other civil government	—	—	—	—	1	—	1	—	1	—	1	—	1	—	5
U.S. commercial	—	1	—	1	2	3	5	6	6	7	7	7	7	5	57
Foreign	1	1	2	—	1	3	4	5	5	6	7	6	7	4	52
DOD (preliminary rev. 10)	—	1	2	5	5	7	8	11	11	12	8	11	10	8	99
Subtotal	1	6	7	11	16	21	29	34	38	38	38	38	38	29	344
Refights	–	–	1	1	1	2	2	2	2	2	2	2	2	2	21
Total	1	6	8	12	17	23	31	36	40	40	40	40	40	31	365
Vandenberg Air Force Base:															
NASA	—	—	—	—	1	—	2	2	3	3	5	4	5	3	28
Other civil government	—	—	—	—	1	—	1	1	2	2	2	2	2	2	15
U.S. commercial	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Foreign	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
DOD (preliminary rev. 10)	—	—	—	3	3	7	5	8	9	9	7	8	7	5	71
Subtotal	—	—	—	3	5	7	8	11	14	14	14	14	14	10	114
Reflights	—	—	—	—	—	—	1	1	1	1	1	1	1	1	8
Total	—	—	—	3	5	7	9	12	15	15	15	15	15	11	122
Traffic model total	1	6	8	15	22	30	40	48	55	55	55	55	55	42	487

SOURCE: National Aeronautics and Space Administration

in space construction for space science and applications;

- ***Large space structure*** experiments—to test the ability to construct large structures in space;
- ***Liquid-fueled*** upper stage—an upper stage for use with the shuttle, that will be powered by a liquid fuel rather than solid propellant, thereby providing greater controllability and payload capacity.

EXPENDABLE LAUNCH VEHICLES

The existing Government expendable launch vehicles used for routine civilian launches now (Scout, Delta, Atlas, and Centaur) are scheduled to be phased out by about 1985 or 1986. Should the Centaur be selected for the liquid-fueled shuttle upper stage, its production will continue, but not as an Earth to Earth-orbit launch vehicle. Figure 6 illustrates the normal payload capacity for these ELVS.

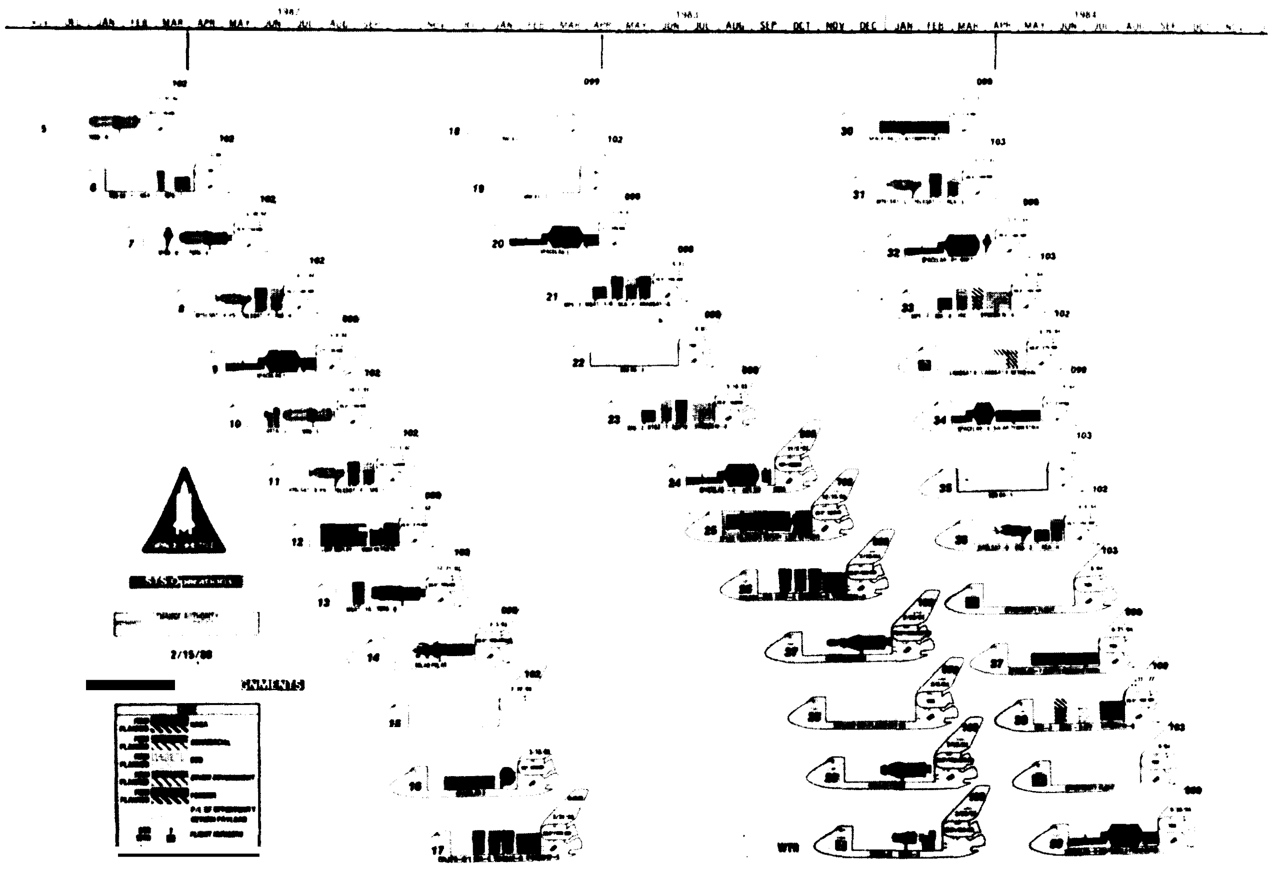
As previously mentioned, the U.S. Government is the only entity in the United States currently launching payloads into space. However, at least one privately owned U.S. company, Space Services, Inc., has indicated that its Percheron launcher will be ready in the near future (1 to 2 years). Maximum payloads for the Percheron are planned to be 700 kg into LEO by 1982, and 200 kg into geosynchronous orbit by 1983.

Space Construction

NASA is planning numerous experiments to test and demonstrate the ability and utility of constructing objects in space. It is clear that space platforms for operational or experimental work will need to be constructed in space because their size will likely preclude launching them in one piece from Earth. Component (beam) builders have been tested on Earth and await testing in space. Should a permanent orbiting space station be included in the space program, its construction will of necessity be carried out in space. In addition, if solar power satellites are deployed, they will have to be constructed in space.

Design requirements are being established for both manned and unmanned permanent platforms that will incorporate evolutionary power systems. NASA is analyzing the feasibility and benefits of low-Earth orbital science and applications space platforms, which would aggregate

Figure 5.—Shuttle Manifest Through 1984



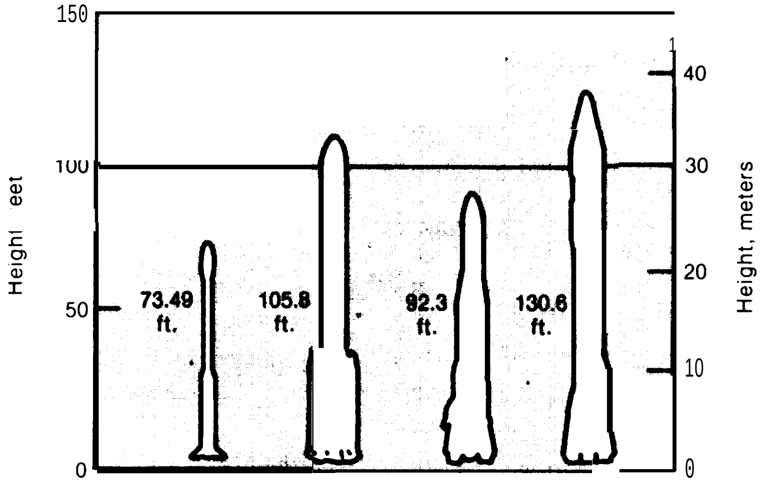
SOURCE National Aeronautics and Space Administration

many long-duration space experiments on unmanned, shuttle-tended platforms. The postulated initial system could accommodate science and applications payloads, demonstrate on-orbit servicing and payload exchange, conduct multidisciplinary investigations, and provide an evolutionary space power system. It could **grow to include** a capability for materials processing experiments, and eventually a habitat for life science and human research (fig. 7).

NASA is also studying a large communications platform that could alleviate the potential saturation of orbit arc and frequency spectrum by aggregating most communications payloads on a common support bus. This platform would be serviced and upgraded remotely by a teleoperator (also under study). For the longer range, NASA is studying a permanent, manned Space Operations Center to establish, service, upgrade, and operate both the low- and high-altitude platforms. Its future potential uses could be to tend and refurbish a reusable orbital transfer vehicle orbiting between low and geostationary orbits and ***to*** construct and assemble large orbiting structures.

In order to plan for support of future possible permanent platforms and facilities, NASA intends to extend its research into a series of developmental test flights and space demonstrations in large space structures, satellite services near to and remote from shuttle, including satellite placement, retrieval and repair, and proof test of a satellite tethered from the orbiter.

Figure 6.—Current NASA Expendable Launch Vehicles



a) Payload values are for east launch from ESMC for Delta and Atlas Centaur
b) Scout values are for launch from Wallops
c) Atlas E/F values are for launch from WSMC and use of a TE 364-4 AKM

SOURCE: National Aeronautics and Space Administration

Figure 7.—initial Space Station Conception

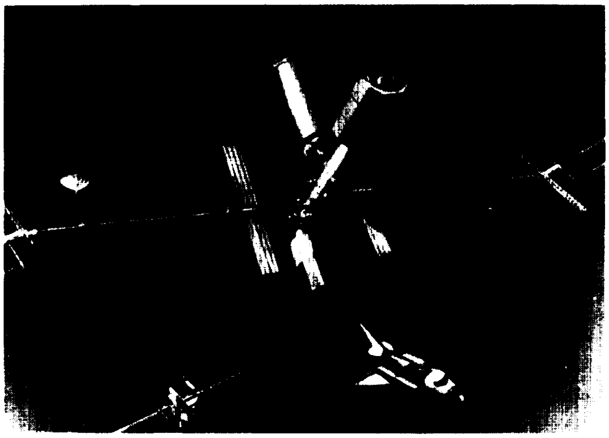


Illustration credit: National Aeronautics and Space Administration

Solar Power in Space

The constancy and strength of sunlight in Sun synchronous or geosynchronous orbits makes the conversion of sunlight to electrical power especially attractive either for use in space or for transmission to terrestrial receivers. Currently, the only active program in the United States is NASA's program to provide an orbiting photovoltaic power supply that could be used by a spacecraft, including the shuttle, to supplement its normal power supply. A 25 kW module can supply power for a spacelab or construction mission of 60 days or more. After 60 days the flight would be limited by such factors as food and drinking water. The module could also supply plug-in power for free-flying payloads that would dock

with it, and it could be detached and parked in orbit between shuttle missions. One version could itself fly free of the orbiter with instruments for, say, studying the Sun or Earth. Another could be attached to a free-flying spacelab for long-duration missions like observing the Sun continuously through two or more 28-day solar cycles or studying plants or animal specimens through several generations.

The solar power satellite (SPS), originally proposed in 1968, was the subject of major studies by NASA, the Department of Energy, the National Academy of Sciences, and OTA[4] (fig. 8). The latter two studies concluded that, although SPS was technically feasible, its high initial cost, environmental and health uncertainties, and lower estimates for the future demand for electricity preclude a major research effort at this time. OTA identified possible research funding levels that range from $0 to $30 million. There are no specific research funds for SPS in the 1982 Federal budget.

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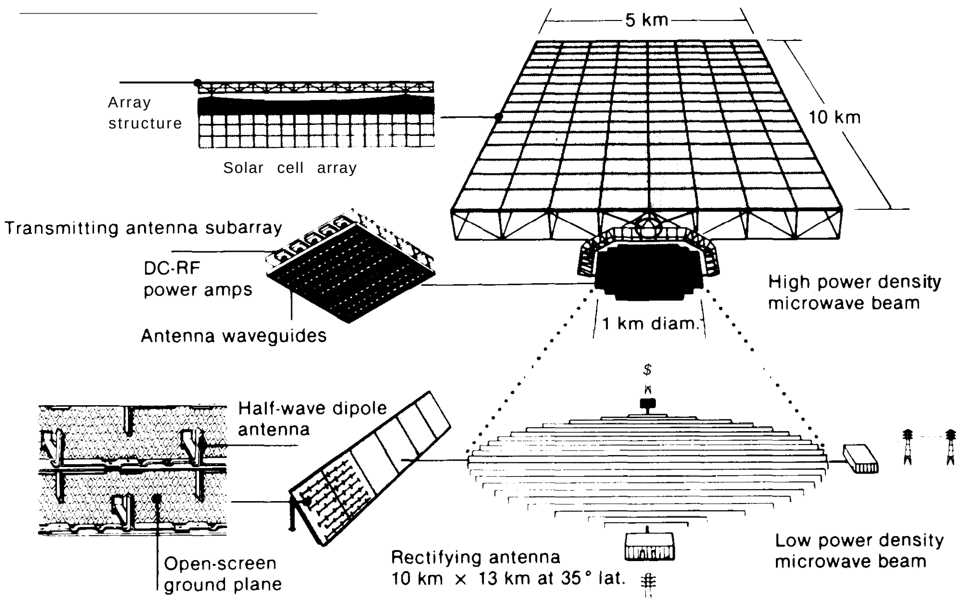
[4] **U.S. Department of Energy, Program** *Assessment Report Statement of Findings,* **NASA/DOE, Satellite Power Systems Concept Development and Evaluation Program, November** 1980; **National Academy of Science, Electric Power** *From Orbit:* **A** *Critique* **of a** *Satellite Power System,* **1981; Office of Technology Assessment, Solar** *Power Satellites,* **OTA-E-144 (Washington, D. C.: U.S. Government Printing Office, August 1981.**

Figure 8.—Solar Power Satellite Reference System



SOURCE National Aeronautics and Space Administration.

Space Science

Although OTA was not asked to assess space science, we felt it necessary, as a point of information, to describe the current U.S. space science programs. Parts of the life sciences program do have implications for the application of space technology for human benefit. This area is centered in NASA and utilizes space systems, supported by ground-based and airborne observations, to conduct scientific investigations to advance our knowledge of the Earth and interstellar space, the other stars of our galaxy, and the universe as a whole. NASA also conducts a life sciences program to further the exploration and use of space by studying space biology and medicine and the origin and evolution of life. Near-term activities focus on investigations of human physiology and of the effects of the space environment on man.

The Office of Space Science and Applications at NASA funds the following science programs, though the funding levels of some may be reduced.

PHYSICS AND ASTRONOMY PROGRAM

The major objective of the physics and astronomy program is to increase our knowledge and understanding of the solar terrestrial space environment and the origin, evolution, structure, and composition of the universe, including the Sun, the stars, and the other celestial bodies. Space-based research is being conducted to investigate the physics, chemistry, and transport processes occurring in the Earth's magnetosphere, ionosphere, and atmosphere, and the responses of the transport processes to solar phenomena and variability; the structure and dynamics of the Sun and its long- and short-term variations; cosmic ray, X-ray, gamma ray, ultraviolet, optical, infrared, and radio emissions from stars, interstellar gas and dust, pulsars, neutron stars, quasars, black holes, and other celestial sources; and the law governing the interactions and processes occurring in the universe. Many of the phenomena being investigated in the physics and astronomy program are not detectable from ground-based observatories because of the obscuring or distorting effects of the Earth's atmosphere.

HIGH ENERGY ASTRONOMY OBSERVATORIES (HEAO) DEVELOPMENT

A major scientific objective of the HEAO program is to observe and investigate not only those)(-ray sources that are already known, but also a much larger number which, because of their distance or their low intensity, remained undetected prior to HEAO. This work has detected classes of intrinsically weak X-ray sources within our own galaxy, as well as stronger sources outside our galaxy. Other equally important objectives include the observation of rare species of cosmic rays, which are crucial to our understanding of heavy element formation, and the search for nuclear gamma ray lines, which are important in understanding the origin of the elements. This program promises to advance our understanding of newly discovered processes that release extraordinary amounts of energy. It will also enhance our understanding of the creation of matter, and deepen our knowledge of observed phenomena such as quasars, pulsars, novae, and supernovae.

SPACE TELESCOPE (ST) DEVELOPMENT

The space telescope is expected to make a major contribution to understanding the stars and galaxies, the nature and behavior of the gas and dust between them, and the broad question of the origin and scale of the universe.

It will enhance the ability of astronomers to study radiation in the visible and ultraviolet regions of the spectrum. Because of its location above the atmosphere, it will be more sensitive than ground-based telescopes of comparable diameter and will record greater detail about the objects under study. It will make it possible to look far into the distant past of our universe.

The telescope should also contribute significantly to the study of the early stages of stars and the formation of solar systems and to the observation of such highly evolved objects as supernova remnants and white dwarf stars. With it we may be able to determine the nature of quasars, and the processes by which they emit such enormous amounts of energy. It will also be possible to study nearby individual stars and perhaps determine if they have planetary systems.

No budget cuts are foreseen for the space telescope.

GAMMA RAY OBSERVATORY (GRO) DEVELOPMENT

The objective of the GRO program is to measure gamma ray radiation from the universe in order to explore the fundamental physical processes powering it: Certain celestial phenomena can be studied only at gamma ray energies. These include direct evidence of the synthesis of the chemical elements; high-energy astrophysical processes occurring in supernovae, neutron stars, and black holes; gamma ray burst sources; diffuse gamma ray radiation and unique gamma ray-emitting objects that may exist. Gamma rays represent one of the last frontiers of the electromagnetic spectrum to be explored, because the required detector technology has only recently been developed. The low flux levels of gamma ray quanta, and the high background they produce through their interaction with the Earth's atmosphere, coupled with the demand for better spectral, spatial, and temporal resolution of source features, combine to require that large gamma ray instruments be flown in space for a prolonged period. Observations of gamma rays are likely to provide unique information on the most astronomically intriguing objects yet discovered: quasars, neutron stars, and black holes.

EXPLORER DEVELOPMENT

The Explorer program provides the principal means of conducting astronomical studies and long-term investigations of solar physics and of the near-Earth interplanetary environment that have limited, specific objectives and do not require major satellite observatories. Included in the present program are missions to study atmospheric and magnetospheric physics; magnetospheric boundaries; interplanetary phenomena; and X-ray, ultraviolet, and infrared astronomy.

SUBORBITAL PROGRAMS

The sounding rocket program provides versatile, relatively low cost research tools that complement the capabilities of balloons, aircraft, free-flying spacecraft and the space shuttle in all the space science disciplines, including the study of the Earth's ionosphere and magnetosphere, space plasma physics, stellar astronomy, solar astronomy, and high-energy astrophysics. Activities are conducted on both a domestic and an international cooperative basis. The current level of activity is about 60 rocket flights per year.

THE PLANETARY PROGRAM

This program includes the scientific exploration of our solar system; the planets, their satellites, the comets and asteroids, and the interplanetary medium. The program objectives are to understand the origin and evolution of the solar system, to understand the Earth through comparative studies with the other planets, and to understand how the appearance of life in the solar system is related to the chemical history of the system.

The strategy that has been adopted calls for equal study of the terrestrial-like inner planets, the giant gaseous outer planets, and the small bodies (comets and asteroids). Missions to these planetary bodies start at the level of reconnaissance and exploration, to achieve the most fundamental characterization of the bodies, and proceed to a level of detailed study, The reconnaissance phase of inner planet exploration began in the 1960's, and has now been completed.

Mars has provided a program focus because of its potential as a site of biological activity, and the Viking landings in 1976 carried out the exploration of this planet forward to a new, high level of scientific and technological achievement, setting the stage for the next step of detailed study. Analyses of the Moon rock samples returned by Apollo continue to be highly productive, as new insights into the early history of the inner solar system are achieved and as our theoretical concepts are revised accordingly. The continuing Pioneer Venus mission is taking the study of our nearest neighbor, and closest planetary analog, beyond the reconnaissance stage to the point where we have made a basic characterization of the massive cloud-covered atmosphere of Venus.

The Galileo mission will conduct direct and long-duration studies of Jupiter. The objectives of this program are to conduct a comprehensive exploration of Jupiter, its atmosphere, magnetosphere, and satellites, utilizing a new deep spacecraft concept that combines both remote sensing and direct measurements on an orbiter spacecraft with separate atmospheric probe. Galileo is the only planetary program still under development and is scheduled for launch in 1984.

MISSION OPERATIONS AND DATA ANALYSIS

The mission operations and data analysis program funds the operations phase of planetary missions after development, launch, and initial inflight checkout are complete. IT also provides for multi mission flight support. Currently, active planetary missions being supported within mission operations and data analysis are Voyager, Pioneer Venus, Pioneer 6-II, Helios, and Viking.

The objective of the Voyager mission to the outer planets is to conduct scientific studies of the Jupiter and Saturn planetary systems, including their numerous satellites and the rings of Saturn. While the two spacecraft are cruising to the outer planets, they are also performing continuing investigations of the interplanetary medium. Since their launches in 1977, the two Voyager spacecraft have encountered both Jupiter and Saturn and returned spectacular data and pictures.

Subsequent to the Saturn encounters, the spacecraft will continue to provide data on the interplanetary medium. Voyager 1 will investigate the outer limits of our solar system and Voyager 2 will go on to Uranus and Neptune.

LIFE SCIENCES PROGRAM

The objective of the life sciences program is to conduct studies in the areas of space biology and medicine, and thereby to expand scientific knowledge of the origin and evolution of life, The realization of this objective, which is intimately linked to our understanding of the basic mechanisms of biological and medical processes, is achieved through a program of research conducted both on Earth and in space. The near-term activities will help us to discover and investigate the effects of the space environment on humans to facilitate their safe, useful participation in space activities. The life sciences program utilizes a composite of disciplines addressing all space-related problems in biology and medicine.

The life sciences program is composed of three major programs. The first consists of flight and ground-based experiments, whereby the physiological effects of the space environment on humans are explored. The unique properties of space (e.g., microgravity, radiation, etc.) provide, for the first time in our history, an opportunity to explore significant problems in biology under a controlled set of conditions that cannot be adequately duplicated in laboratories on Earth. The second is the continuous inflight observation of crews venturing in space and the testing and refining of countermeasures and establishing requirements in human space exploration. The third is the studies in exobiology, with special emphasis on a problem of profound philosophical and scientific significance: origins and the distribution of life in the universe.

The life sciences operational medicine program is the catalyst responsible for bringing the science, technology, and practice of medicine to bear on solving the problems of sustaining, supporting, and protecting individuals working in the space environment. This includes assurances that physical welfare and performance are preserved and that adequate treatment of inflight illnesses or injuries is provided.

The biomedical research program objective is to develop the basic medical knowledge needed to enable men and women to operate more effectively in space, The program is organized into discrete elements with each designed primarily to rectify a particular physiological problem expected to affect the human organism in prolonged or repetitive space flight. Thus, motion sickness, bone loss, and hormonal disturbances are the subjects of a continued search for mechanisms and countermeasures. The program is largely dependent upon the use of ground-based analogs of space flight.

The space biology activity will explore the role of gravity in life processes and use gravity as an environmental tool to investigate fundamental biological questions. Specific objectives are to: 1) investigate and identify the role of gravity in plant and animal cellular processes, embryonic development, morphology and physiology; 2) identify the mechanisms of gravity sensing and transmission of gravity-perception information within both plants and animals; 3) identify the interactive effects of gravity and other stimuli (e.g., light) and stresses (e.g., vibration) on the development of metabolism of organisms; 4) use gravity to study the normal nature and properties of living organisms; and 5) extend the limits of knowledge about plant and animal growth and metabolism to provide for long-term survival and multigeneration reproduction of life in space. This program provides basic ground-based information in support of future space flight experiments and life support systems environment. This includes assurances that physical welfare and performance is preserved and that adequate treatment of inflight illness or injuries is provided.

Exobiology is the study of the origin, evolution, and distribution of life and life-related molecules on Earth and beyond. Sophisticated analyses of life as we know it, its chemical precursors and its origin, coupled with extrapolation to extraterrestrial environments, affords a unique opportunity to address a most fundamental question regarding the existence of such processes beyond the Earth. Theories about chemical evolution and the origin of life are being refined to reflect results from the most recent planetary and astronomical explorations. The current research program also is uncovering an intimate association between the origin and evolution of life on Earth and the processes that shaped the evolution of the solar system itself. These discoveries have highlighted gaps in our knowledge which, when completed as the program expands, will ultimately allow tests of the concept of universality of biological processes.

It may be useful to describe one additional space science program that has now been significantly cut back, because this cutback has ramifications for future international cooperation in space applications.

The international solar polar mission (ISPM) was a joint NASA and European Space Agency mission designed to obtain the first view of the solar system from a new perspective—a view from far above and far below the plane in which the planets orbit the Sun's equator, i.e., over the poles of the Sun. The two spacecraft would have aided in the study of the relationship between the Sun and its magnetic field and particle emissions (solar wind and cosmic rays) as a function of solar latitude, and hence might have allowed us to gain insight into the possible effects of solar activity on the Earth's weather and climate. The objective of the international solar polar mission was to conduct an exploration of those regions of the heliosphere above and below the equatorial plane of the Sun. Observations in the extreme, high-latitude regions of the sun have not been made before, and evidence indicates that this region of space is greatly different from the region in which the Earth is located.

The U.S. spacecraft for ISPM was canceled on account of budget constraints. The issues raised by its cancellation are discussed in chapter 7.

PUBLIC ATTITUDES ON SPACE

Democratic government is based on the premise that there should be some linkage between public attitudes and political choice, not only in general but also with respect to specific issues on the public agenda. This linkage is not a one-way path, of course; public officials are leaders, teachers, and molders of public attitudes and opinion as well as representatives of the public in the political process. Thus, the following account of public attitudes about the space program needs to be interpreted with the understanding that general public opinion is only one determinant of public policy, and that its influence is rarely direct. Public opinion more frequently acts as a general constraint, setting boundaries within which political leaders are free to chose, or as an indirect shaping influence on the attitudes of elites inside and outside of government; most often, it is these attitudes that are closely correlated with specific policy choices.

From this analysis it follows that:

1. During the early years of the U.S. space program, the general public was willing to accept the interpretation of society's leaders as to the significance of space activities. This made it possible for the United States to first adopt a moderate response to Soviet space achievement, then to reverse policy and to enter into competition with the Soviets, even though public attitudes seemed to be opposed to such competition.
2. More recently, public understanding of the space program, and a supportive public attitude toward that program, have increased to the point where they may have political impact. Although an official's position on space-related issues may not be a crucial determinant of electoral success, prospace attitudes, and particularly, groups organized to reflect them, appear to be having some impact in influencing public policy with respect to the U.S. space program.

It is important, however, even if the second of these propositions is accepted, to recognize that "while it has considerable intellectual interest and entertainment value, space exploration is not a daily concern of the general public. . . . The levels of interest and information in this area are especially low."[5] Thus it is likely that public attitudes will provide the background, but not much more, against which national space policy will continue to be formulated.

Public Opinion and Space Policy: 1965-80

A striking example of a leadership decision not being constrained by apparent public opinion is the U.S. commitment to a manned lunar landing. In the very month that President John F. Kennedy announced that he was setting as a national goal a lunar expedition before 1970, the Gallup Poll reported that the public was opposed by a 58 to 33 percent margin to spending the up to $40 billion such an enterprise would require, Until very recently, only once since 1965 has the percentage of U.S. adults calling for the United States to do more in space exceeded the portion believing that the Government should do less. Figure 9 compares this division of opinion for the period

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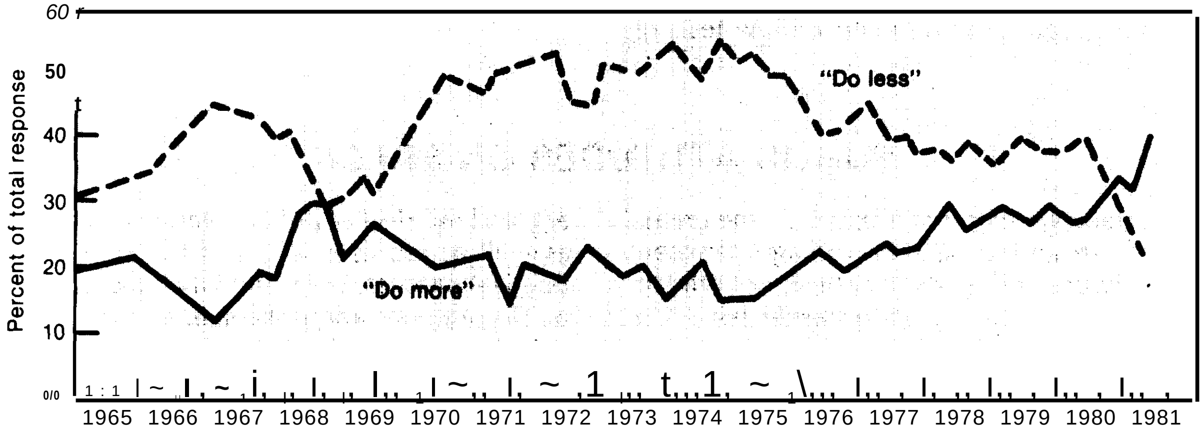
[5] National Science Board, Science *Indicators, /980,* p. 169.

Figure 9.–Long-Term Trend Polling Results of U.S. Public Opinion on the Federal Space Effort



NOTE: Responses to question of whether government should "do more" or "do less" In support of space exploration, 1985-1981.

SOURCE: For 1965-1975, Herbert Krugman, "Public Attitudes toward the Apollo Program, " Journal of Comrnurr/cations, vol. 27, No. 4 (1977), More recent data are derived from Trendex Polls taken for the General Electric Co.

from 1965 to 1981; the recent shift toward a markedly more prospace position is clear from this chart.

Table 10, which reports opinions for the 1973-**80 period,** is even more revealing, both in terms of the longer term trends and in terms of the current uprising in prospace opinion. Only in recent years have space "antagonists" comprised less than an absolute majority, and the explicitly prospace group grew only slowly, from **7.4** percent in 1973 to 11.6 percent in 1978. Most recently, however, the figure for those believing the United States is spending too little on space has jumped to 18 percent, and space antagonists are now only 39 percent of the total. The size of the "space neutral" segment has stayed constant, and thus the gain in support for expanded space spending appears to reflect a real shift in opinion. In 1980, for the first time, those of the opinion that space spending should not be lowered outnumbered those holding the opposite view, 53 percent to 39 percent.[6]

While prospace opinion appears ***to*** be increasing, the priority assigned to the space program has historically remained low. Tables 11 and 12 demonstrate this both for Government priorities in general (table 11) and for priorities within science and technology (table 12). What is most relevant in table 11 is that only the "military, armaments, and defense" category showed a greater increase in percentage in favor between 1977 and 1980 than did the "space exploration program," although this increase only moved space one rank up the priority scale. According to one analyst, "the increasing approval of space activities among Americans over the past several years is

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[6] Robert D. McWilliams, **"The Improving Socio-Political Situation of the American Space Program in the Early 1980' s," paper prepared for Fifth Princeton/AIAA Conference *on* Space Manufacturing, May 1981, p. 2.**

Table IO.—Distribution of Opinion Toward Federal Spending on the Space Program: 1973 Through 1980 (percentages)

	1973	1974	1975	1976	1977	1978	1980
Too little	7.4	7.7	7.4	9.1	10.1	11.6	18.0
About right	29.3	27.5	30.1	28.0	34.4	35.0	34.6
Too much	58.4	61.0	58.1	60.2	49.6	47.2	39.1
Don't know	4.7	3.6	4.4	2.5	5.9	6.5	8.3
Total	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**

SOURCE National Opinion Research Center Polls as reported in Robert D. McWilliams, "The Improving Socio-Political Situation of the American Space Program in the Early 1980s, " paper prepared for Fifth Princeton/AIAA Conference on Space Manufacturing, May 1981

Table 11.—Percentages of Americans Favoring Increased Funding, and Relative Priority Rankings, for 11 Areas of Federal Government Spending, 1977 and 1980

	1977 percent	1977 rank	1980 percent	1980 rank	Percent increase
Halting the rising crime rate	70.0	1	72.0	1	2.0
Dealing with drug addiction	59.5	2	64.5	2	5.0
Improving-protecting Nation's health	58.5	3	57.1	4	– 1.4
Improving-protecting the environment	51.2	4	50.8	6	– 0,4
Improving Nation's education system.	49.5	5	54.9	5	5.4
Solving problems of the big cities	46.9	6	45.8	7	-1.1
Improving conditions for blacks.	27.3	7	26.2	8	– 1.1
Military, armaments and defense	25.7	8	60.2	3	34.5
Welfare	13.0	9	14.0	10	1.0
Space exploration program	10.7	10	19.6	9	8.9
Foreign aid.	3.7	11	5.4	11	1.7

SOURCE' Robert D. McWilliams, "The Improving Socio-Political Situation of the American Space Program in the Early 1980s," paper prepared for Fifth Princeton/AIAA Conference on Space Manufacturing, May 1981

Table 12.—Public Priorities for Federal R&D Spending

	Most preferred		Least preferred	
Funding objective	Response	Rank	Response	Rank
Improving health care	815	1	60	12
Developing energy sources and conserving energy	754	2	40	14
Improving education	630	3	55	13
Reducing crime	587	4	82	11
Developing or improving methods for producing food	368	5	253	8
Reducing and controlling pollution	358	6	113	10
Developing or improving weapons for outer space	266	7	403	6
Preventing and treating drug addiction	259	8	195	9
Developing faster and safer public transportation	210	9	430	5
Improving the safety of automobiles	155	10	284	7
Finding better birth control methods	139	11	705	1,5
Discovering new basic knowledge about man and nature	135	12	577	4
Exploring outer space	99	13	705	1.5
Predicting and controlling the weather	60	14	592	3

SOURCE: Institute for Survey Research, Temple University, *National Survey of the Attitudes of the U.S. Public Toward Science and Technology*, submitted to National Science Foundation, May 1980, pp. 178-180. (This was a survey of 1,635 people over 18. Respondents were asked: "Which 3 areas . . . would you *most* like to receive science and technology funding from your tax money?" and "Which 3 areas . . . would you *least* like to have science and technology funding from your tax money?"

not a trend that is riding mainly on the coattails of militarism or growing faith in science and technology. Rather, it seems that Americans may be coming to view the space program as being conducive to the achievement of other types of goals of which they are in favor. "7

One indication of what the public expects from space exploration is presented in table 13. A national survey taken for NSF asked adults to identify benefits they believed would result from exploring outer space. Listed in table 13 are those benefits mentioned either first or second by respondents. What is striking about the results is the high ranking given to an indirect benefit of the program ("improve other technologies") and the low rankings given to direct economic benefits ("find industrial use," "create jobs and other economic benefits"). Compared with other technology-related issues such as nuclear power or chemical food additives, a greater proportion of Americans see space exploration as producing substantially more benefits than potential harm.[8]

It is possible to construct a profile of those who most "support" and those who most "oppose" the U.S. space program, if "support" and "oppose" are defined as deviations of more than 10 percent from the average of all Americans. Table 14 contains such a profile, Those who support the space program tend to have one or more of the following characteristics: male, between 25 and 34, college-educated, professional or technical employment, working for government, income over $25,000/year, and living in the West. Opponents of the space program tend to be: female, over 65, black, less than a high school degree, laborers and service workers, and under $5,000 income. One more relevant characteristic that emerges from another opinion study is that those who support increased space spending are significantly more likely to vote than those who believe that too much is spent on space; over 72 percent of those who supported an increase in space budgets in 1980 voted in the 1976 Presidential election, while only 56 percent of those calling for reduced spending voted that year.[9]

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[7] 1 bid., p. 8

‘National Science Board, op. cit., p. 170.

[9] McWilliams, op. cit., p. 16.

Table 13.—Perceived Benefits From Space Exploration

Benefits	First or second mention
Improve other technologies (e.g., computers)	272
Find mineral or other wealth, other resources, sources of energy	**200**
Increase knowledge of universe and/or of man’s origins	190
Find new areas for future habitation	134
Contact other civilizations, other forms of life	107
Improve rocketry and missile (military) technology.	43
Find industrial use for space	27
Find new kinds of food/places to raise more food products	26
Create jobs and other economic benefits.	16
Learn about weather and how to control it.	13

SOURCE: Institute of Survey Research, p. 164

Table 14.—Profile of Public Attitudes of Space Exploration: “In General, Do You Favor or Oppose the Exploration of Outer Space?”

Group characteristics	Percent favor	Percent oppose
All	60	31
Men.	71	22
Women	49	38
Age 25 t0 34	70	23
Age over 65	34	**50**
Black	38	49
O to 8 years of schooling	32	50
9 to 11 years of schooling	40	50
Some college, no degree	74	19
Bachelor’ s degree	79	15
Graduate degree	85	10
Professional or technical job.	78	16
Operatives and laborers	43	43
Service workers	47	41
Work for government	76	17
Under $5,000 income	31	55
$25,000 to $49,999 income	76	17
Over $50,000 income	74	15
Live in West	74	20

[a]Only those characteristics that differ by more than 10 Percent ‘rem overall opinion are included.

SOURCE: Institute for Survey Research, Vo/ *II, Detailed Findings*, p 170.

The demographic makeup of the ‘‘prospace’’ group appears to be undergoing some changes in recent years, although its general characteristics as profiled in table 11 have remained stable. Among those changes:

- recent increases in prospace attitude are much more marked among the most highly educated;
- formerly, “lower” and “working” classes were more antispace than were **“middle” and “upper” classes. Recently, however, the “middle” and “working” have become** more space positive than either “upper” or “lower” class respondents;
- prospace attitudes have increased substantially among whites and only negligibly among blacks; and
- support for space is increasing faster for divorcees than for any other marital class.[10]

There has been a suggestion that the shifts in space-positive attitudes with respect to variables of social class and education “provide a classic example of how social change tends to begin and develop in society. Innovations generally find their beginnings in the ideas and efforts of the more highly educated members of the upper-middle class and, if they survive and grow more prevalent in the upper strata, they then tend to catch on at the lower socioeconomic levels.” The same analyst argues that “the resurgence of space-positivism in America since 1975 was spawned by the upper and middle social classes. The trend then began to spread throughout the general public with the classic pattern that has characterized other prominent American social movements such as the feminist and civil rights crusaders.’” [11]

One of the most striking recent developments in the space policy field is the emergence of a number of organized prospace groups. As the quotation just cited suggests, the aggregation of individual opinions into more-or-less broadly based interest groups with middle and working class roots is part of the traditional pattern by

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[10] McWilliams, op. cit., pp. 10-15.

[11] **Ibid., p. 14.**

which issues are given increased attention on the public agenda. perhaps this is what is happening with respect to space. The following section describes the recent emergence of a space interest group network.

Interest Groups and Space Policy

During the 1970's, interest groups organized around one or a few issues and claiming to represent broad sectors of the general population—so-called "public" interest groups—became an increasingly important influence on public policy. In part, the increased influence came at the expense of political parties as vehicles for articulating, influencing, and implementing the public's policy preferences.[12] Thus the rapid increase in space interest groups in recent years may be a development of political significance. A May 1980 survey of space interest groups identified 39 organizations with nationwide activities.[13] In the past 2 years, and particularly with the transition in administrations, there have been a number of one-time efforts organized ad hoc to mobilize opinion on space policy; these groups have provided a base for such mobilization efforts.

There is an active "Coordinating Committee on Space" that attempts to identify areas of agreement and disagreement among the major pro-space groups; its membership includes 11 of the most active organizations. There are two general types of prospace groups: 1) traditional professional groups, and 2) citizen support groups. Most prominent among the former are:

- ***American Institute of Aeronautics and Astronautics,*** the professional society for people in the aeronautics and astronautics field, with almost 30,000 members.
- ***American Astronautic/ Society,*** a group of individuals with professional interest in space. Current membership is about 1,000.
- ***Aerospace Industries Association,*** a consortium of major aerospace firms that functions as a trade association.
- ***National Space Club,*** a Washington-based group of business and government leaders in the space field.
- ***University Space Research Association,*** a consortium of universities active in space research that operates several facilities under NASA contract.

Among the most active and/or largest of the public interest or citizen support space groups are:

- ***Delta-Vee,*** a citizen-supported, nonprofit corporation that channels public contributions into the support of specific space activities, such as the continued operation of the Viking spacecraft on Mars and a U.S. Halley's Comet Mission.
- ***High Frontier,*** a group formulating a national strategy to make maximum use of space technology to counter the threat of Soviet military power, to replace current nuclear strategy with one based on space defense, and to promote the industrial and commercial potentials of space.
- ***Institute for the Social Science Study of Space,*** which sponsors research and publications related to the social science aspects of space exploration and development.
- ***L-5 Society,*** which emphasizes human settlement in space as a long-term goal. Founded in 1975 by Gerard K. O'Neill, it has broadened its scope to most aspects of space policy. Its membership is between 3,000 and 4,000 individuals.
- ***National Space Institute,*** the largest of the broadly based space groups, with over 10,000 members. Founded in 1975 by Wernher von Braun, its emphasis is on communication with general audiences.
- ***Planetary Society,*** which promotes awareness of and public involvement in planetary exploration and search for extraterrestrial life. Publishes newsletter, supports research, organizes meetings. Has grown to over 100,000 members in just over a year.

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[12] Charles Chafer, "The Role of Public Interest Groups in Space Policy," Jerry Grey and Christine Krop (eds.), *Space Manufacturing III,* Proceedings of the Fourth Princeton/AIAA Conference (New York: American Institute of Aeronautics and Astronautics, 1979), pp. 185-189.

[13] Trudy Bell, "Space Activists on the Rise," *Insight,* August-September 1980, pp. 1, 3, 10, 13-15.

- Space **Foundation,** a private foundation for support of space industrialization.
- ***Space Studies Institute,*** a research performing and supporting group with focus on use of nonterrestrial resources.
- ***World Space Foundation,*** a group supporting research projects to accelerate space exploration (e.g., solar sail).

The purposes of these and other space groups fall into three general categories:

1. educating and informing the public;
2. conducting research themselves; and
3. funding external research.

Recently added to the list are groups explicitly engaging in political activities. There were attempts to organize prospace Political Action Committees (PACS) for the 1980 election, and at least one prospace PAC remains in existence.

The influence of these various organizations and groups on space policy is difficult to estimate. Certainly, as the Reagan administration took office in january 1981 and as the proposed NASA budget was cut several times in the following year, there have been a number of attempts by one or a coalition of these groups to mobilize opinion in support of specific projects (e.g., a mission to Halley's Comet) or for the civilian space program in general. Whether the reductions in the NASA budget would have been even more severe, had not these groups been active, is a question difficult or impossible to answer.

Finally, note should be taken of the emergence of a Congressional Space Caucus, and a supporting Congressional Staff Space Group. This caucus is initially limited to the House of Representatives; its goal is to increase the awareness of Members and staff of the benefits of the Nation's space effort.

Space Achievement and Public Opinion: 1981

With two successful flights of the shuttle *Columbia* and the encounter of Voyager 2 with Saturn, 1981 was a year of spectacular space achievement for the United States. Several public opinion polls have confirmed that the citizens of the United States were quite supportive of these achievements.

- A May 1981 Harris survey, taken less than 1 month after the initial shuttle flight, found 76 percent of Americans calling the shuttle "a major breakthrough for U.S. technology and know-how' and a 63 to 33 percent majority favoring the expenditure of several billions of dollars over the next decade to develop the full potential of the shuttle. The Harris poll noted that "after the 1969 Moon landing, a 64 to 30 percent majority did not feel it was worthwhile to spend an additional $4 billion on the Apollo space program" and commented that "current support for spending on the space program is even more significant in view of the current overwhelming preference for cutting Federal spending. "
- An August 1981 Associated Press-NBC survey found that 60 percent of U.S. adults thought that the United States was not spending enough or was spending about the right amount on the space program, and 66 percent believed that the shuttle was a good investment for the United States.
- An October 1981 Associated Press-NBC poll confirmed the results of the earlier survey, finding that 60 percent of respondents think the shuttle program is a good investment, 30 percent do not, and 10 percent aren't sure.

A further examination of the results of the May Harris poll suggests both that support for the space program is not evenly distributed across all strata of U.S. society and that the reasons for the support differ substantially among respondents (see tables 15 and 16). The August poll found that 49 percent of respondents believed that the emphasis of the Nation's space program should be primarily on national defense, 32 percent cited scientific exploration, 10 percent cited both, and 9 percent were not sure. By October, these responses had shifted, with 43 percent in support of a defense emphasis and 40 percent favoring an emphasis on scientific exploration. In this latter poll, 46 percent of respondents believed that the United States should keep its space program

Table 15.—How Would You Rank the Importance of Various Uses of the Space Shuttle?

	Very important	Only somewhat important	Not very important at all	Not sure
	Percent	*Percent*	*Percent*	*Percent*
Doing experiments with new pharmaceutical products that can help cure disease	82	11	5	2
Developing a military capability in space beyond what the Russians are doing	**68**	**20**	**10**	**2**
Putting new communications satellites in space at a much lower cost	64	25	9	2
Doing scientific research on metals, chemicals, and living cells in space	55	27	16	2
Picking up other U.S. space satellites and repairing them in space	47	32	19	2

SOURCE: May 1981 Harris Survey.

Table 16.—"IS the Space Shuttle Program Worth Spending Severai Billion Dollars Over the Next 10 Years to Develop its Full Potential?"

	Worth it	Not worth it	Not sure
	Percent	*Percent*	*Percent*
Total	***63***	33	**4**
College educated	**71**	26	**3**
Men	76	21	
Women	52	43	**3**
Blacks	45	53	**2**
Republicans	71	***26***	**3**
Democrats	57	***39***	**4**
Conservatives	66	**30**	4
Liberals	57	**41**	2

SOURCE: May 1981 Harris Survey.

separate from the programs of other nations, 32 percent favored a joint space program between the United States and the U. S. S. R., and 15 percent favored joint ventures with other countries, but not with the Soviet Union.

Opinion polls, taken singly, do not reveal fundamental views underlying the shifting tides of opinion. Thus, the facts that by 1981 the success of the shuttle and of the Voyager missions spurred public interest in the U.S. space program and that a clear majority of the public was found to favor the program do not in themselves prove that there is deep public support for space. But, viewed in the context of a quarter century of space activities, the recent upswing in opinion in favor of the space program appears significant.

First of all, current support is part of a long-term trend of increasing support. It cannot, therefore, be explained as the result only of shuttle and Voyager successes. Second, the trend of increasing support coincides with the proliferation and growth of citizens' support groups. As public education about space is perhaps the major overall goal of these groups, their efforts have been the effect, if not the cause, of continued rising interest in space. Third, the Space Caucus, arising as a "back bench" movement within Congress, rather than in response to the leadership, is evidence for a genuine space constituency, i.e., one whose real interests, economic, political, or scientific, are at stake. These three conditions suggest that public awareness of space issues is increasing and that official space policy may begin to receive more constant scrutiny among at least the attentive public. This would seem to bode well for those who believe that increased understanding of the benefits of U.S. activity in space will lead to continued and firmer public support for that activity.

Chapter 6

RELATIONSHIPS BETWEEN THE CIVILIAN AND NATIONAL SECURITY SPACE PROGRAMS

Contents

FIGURE

Chapter 6

RELATIONSHIPS BETWEEN THE CIVILIAN AND NATIONAL SECURITY SPACE PROGRAMS

INTRODUCTION

Over the years, the National Aeronautics and Space Administration (NASA), the Department of Defense (DOD), and other Federal agencies have evolved a set of interlocking responsibilities for U.S. space activities. NASA is designated as the lead agency for most U.S. civilian space efforts. DOD, in accordance with the National Aeronautics and Space (NAS) Act of 1958, undertakes "activities peculiar to or primarily associated with the development of weapons systems, military operations, or the defense of the United States (including the research and development (R&D) necessary to make effective provision for the defense of the United States). " Responsibility for coordinating the efforts of the civilian and the military programs was initially vested in the National Aeronautics and Space Council (see ch. 10) and a Civilian-Military Liaison Committee, although both were later abolished under Presidential reorganization plans. It was explicitly recognized that the President was ultimately responsible for dividing specific responsibilities between DOD and NASA.

The premise that there is a need for separate civilian and national security space programs has been examined and reaffirmed by several high-level policy reviews in the intervening years–each concluding that **the characteristics of the primary missions of each program justified the distinct institutional structures that had been developed.** These reviews also affirmed that relations between the two programs should be continually scrutinized and that opportunities for cooperation or better coordination should be sought.

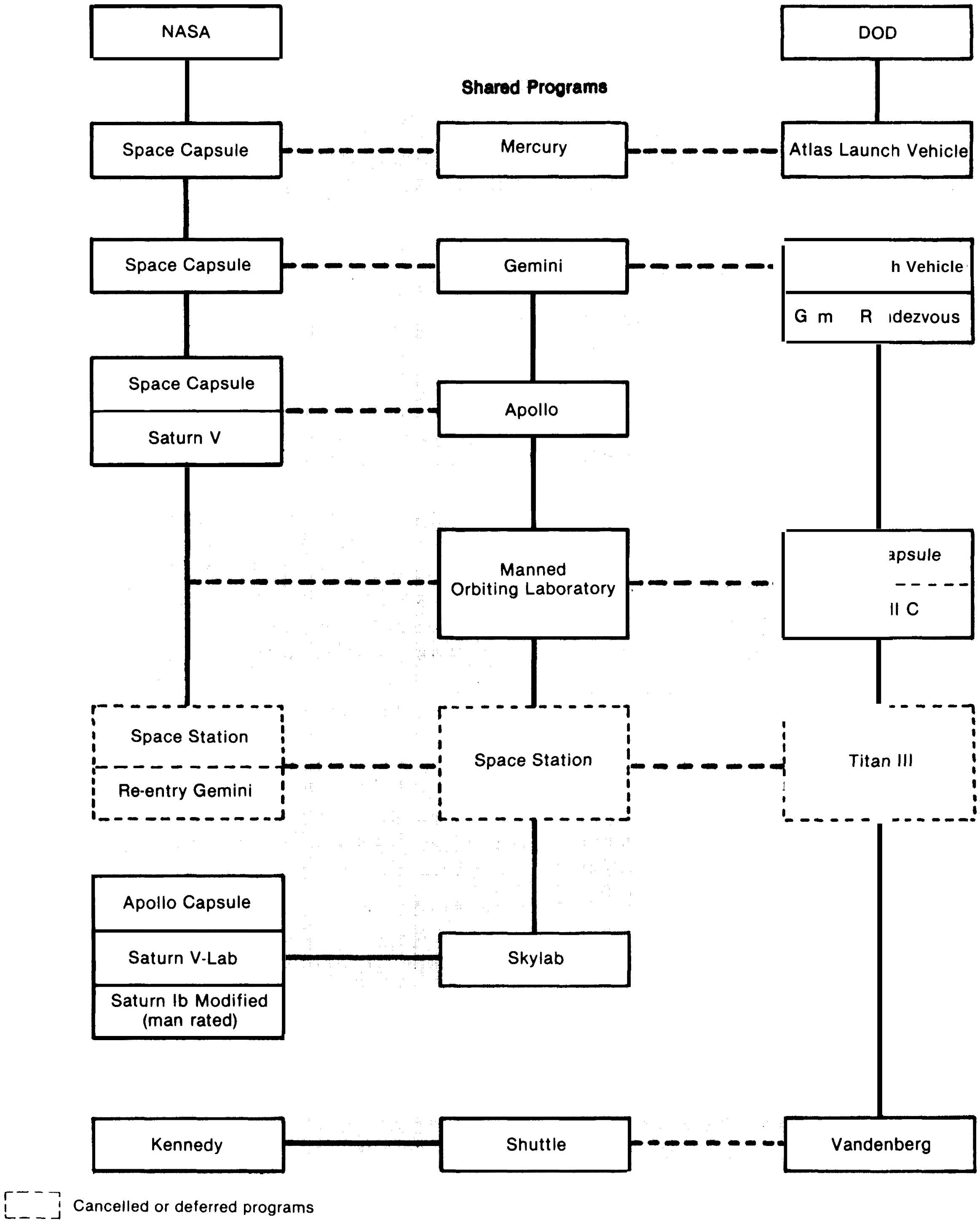
Now that NASA and DOD have been conducting space programs for nearly 25 years, under separate charters but with overlapping interests, it is appropriate to consider the current status and probable future of their relationships in light of overall U.S. civilian space policy. The recent rapid growth and projections of even more rapid future increases in military space programs and budgets make such a reconsideration essential.

Access to Classified Information

Any analysis of the relationships between the civilian and the national security programs that is intended for public dissemination has to confront the problem of access to classified information. Information is classified and placed under restrictive security controls if its unrestricted publication is deemed to harm the national security. Classified data were not used in the preparation of this report. Though discussion of the implications of classified-unclassified program relationships at an unclassified level is necessarily incomplete and sometimes unconvincing, it is nevertheless the only available approach to presentation of such matters to the general public. The material that follows has been written in such a way as to provide sufficient insight into the types of issues the classified programs generate and to ensure that the analyses and discussion of options are reasonable. Inevitably, there will be conclusions or observations that could be evaluated more completely in a classified document.

It must also be recognized that there are different degrees of classification within the military/intelligence programs. The most highly classified are the so-called "National Technical Means" and related systems; information about these systems is very closely kept, even within the national security community. These systems are mostly involved in strategic reconnaissance. Many military systems, on the other hand, such as communications and navigation satellites, are not themselves classified, though certain details of the technologies involved are kept secret.

Cooperation Between DOD and NASA in U.S. **Manned Space Programs**



SOURCE: Office of Technology Assessment.

Summary Assessment

Separate Programs

Space systems provide an increasing number of vital services to support a variety of military and intelligence missions. Continued technological advances, along with the need to counter an increasing level of military space activities by the Soviet Union, will expand the range of desirable national security programs. Similarly, on the civilian side advancing technology will make possible space activities that could contribute significantly to a number of high-priority national objectives. These include: 1) to enhance the image and prestige of the United States through continuing man-in-space activities; 2) to provide a base for commercial space services, most notably for communications; 3) to conduct research; 4) to extend the technology base for space and launching systems; and 5) to perform valuable public services such as meteorological observations, storm warning, and other **Earth observation or communication tasks.**

In today's environment of growth in expenditures for national security combined with reductions in civilian activities, it is necessary to consider the continued appropriateness of separate programs and separate institutions. This is especially important with the advent of the space transportation system, which represents a large new area of common interest and new opportunities for technology sharing. Three basic options seem possible: 1) separate civilian and military programs; 2) independent space R&D agency for all Federal space programs, civilian and military; and 3) absorption of NASA by DOD and other Federal agencies. These options are discussed under the heading "Institutional Change. "

Technology Transfer

Classification barriers necessarily protect sensitive national security information, but their existence disposes many in the civilian community to attribute unknown but vastly superior capabilities to classified systems. This leads to the claim that if military technology could be transferred more rapidly and more thoroughly to the civilian sector, civilian programs would benefit greatly from these superior capabilities. This view is, for the most part, oversimplified and fails to recognize important differences in agency missions and the resulting needs for space systems. Different mission objectives entail different emphases on performance characteristics and other design considerations in the development and adaptation of advanced technology. For example, a military system may have to be able to operate in a hostile environment, so that military specifications are frequently more stringent than those for civilian purposes.

Nevertheless, the adequacy of technology transfer between civilian and national security programs remains an important issue that will be examined in some detail in this chapter, The following observations summarize this analysis:

- Technology flows in both directions, and both sectors have benefited from such transfers. General-use space technology is transferred with relativ ease; mission-specific technology only with great difficulty.
- There are few incentives and, frequently, practical penalties for either a national security or a civilian program manager to enter cooperative technology sharing arrangements with other programs.
- The need to protect certain information and technology for national security purposes limits its accessibility to civilian users.
- Procedures exist to enable selected individuals from civilian agencies to gain access to classified systems and information, but this access is imperfect for a variety of reasons; continued management attention is needed to keep these procedures functioning effectively.

Asymmetrical Relationships

The need to protect national security space activities and products results in a continuing asymmetry in the relationships between the two programs. In general, systems operated by DOD are of high national priority; they are established in response to needs that are not easily questioned by those outside of the national security decision-making structure. Similarly, the determination of the boundary between classified and unclassified technology is made within the national security community. As a result, limitations have been set on the allowable performance of civilian systems. These limitations tend to persist and act as continuing constraints on civilian users; in some cases, the civilian user community does not know the details of the restrictions that exist. There are few opportunities for the civilian community to question these restrictions, except within forums such as the National security Council (NW, where civilian agency interests are inevitably of secondary importance. These asymmetries suggest the need for a forum in which the civilian and national security space relationships can be equitably reviewed from a disinterested perspective, as discussed in chapters **3** and **10.**

National security concerns affect most, if not all, civilian space applications programs; therefore, a discussion of the relationships between the two sectors is especially pertinent to this assessment. An outline of the DOD-operated programs is given in the following section, but the limitations that result from describing them on the basis of unclassified data must be kept in mind.

STATUS OF NATIONAL SECURITY SPACE PROGRAMS

The national security uses of space technology are quite varied; however, they are all "applications" in that space technology is one means to achieve various national security objectives. The United States depends heavily on space-based systems: 1) to conduct continuing surveillance of activities in many areas of the world, particularly those controlled by its potential adversaries, and to monitor compliance with international agreements; 2) to provide timely warning of attacks on the United States and allied territory; and 3) to communicate with U.S. military forces around the world and at sea. The U.S. national security community is also actively exploring other space activities, including: 1) the need to protect both civilian and security assets already in orbit from Soviet antisatellite systems; 2) the ability to assure "freedom of the roads" for U.S. spacecraft and launch vehicles by developing a deterrent in the form of an antisatellite interceptor; 3) and the long-range potential of space-based weapons for defending the United States and its allies against hostile actions. The sum total of these activities comprises a fast growing national security space program; many military analysts see space technology as having a revolutionary impact on national strategy and national power in coming years.[1]

Current Systems

Precise figures regarding expenditures for DOD-supported space efforts are unavailable because many of them are classified. Figure 10 compared published data on spending for civilian (NASA) and military (DOD) space activities. Over the past several years, the national security budget has been growing at a much faster rate than the civilian one, and is now larger in absolute terms than the civilian budget. When one recognizes that the single major item in the NASA budget, the shuttle, will have DOD as its single largest user, the emphasis on national security applications of space becomes even more marked.

Current national security space systems perform (although in a very different context) functions similar to those performed by civilian space systems. Classification of these systems prohibits a full description of them in this analysis;[2] the following brief descriptions are thus intended only to emphasize the support role played by currently operational national security space systems:

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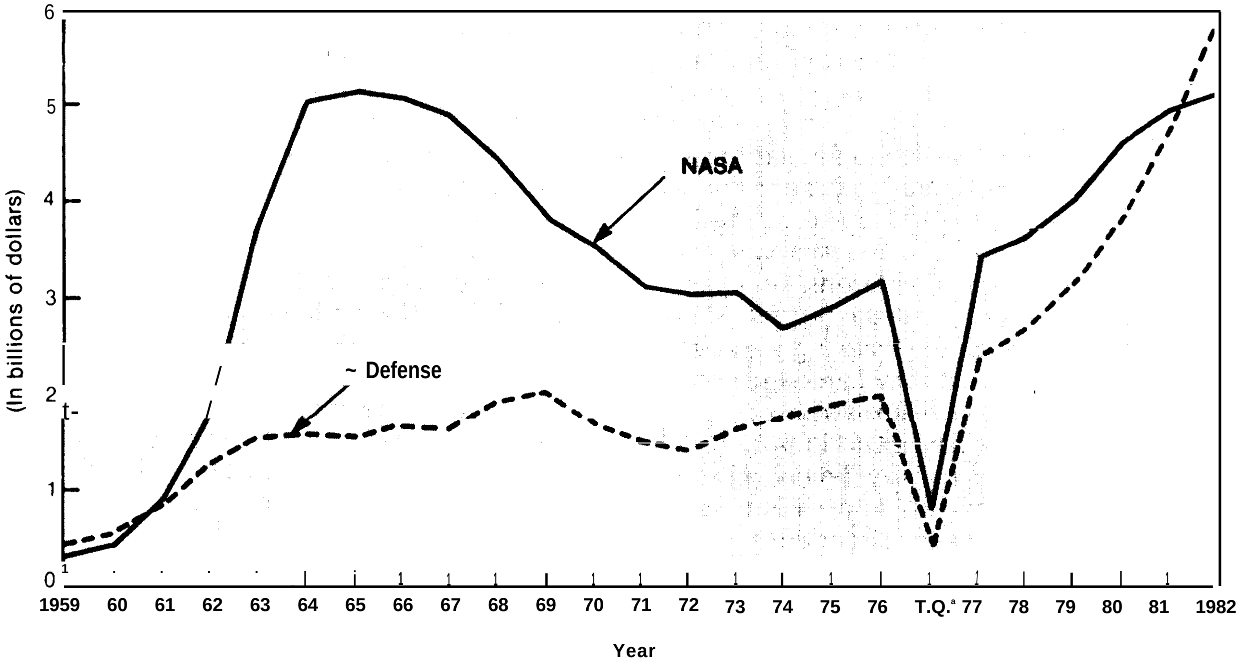
[1] A recent study of the potentials of armed conflict in space is G. Harry Stine, *Confrontation in Space* (Prentice-Hall, 1981); see also the recently published report *High Frontier,* from the Heritage Foundation.

[2] Further information on intelligence and defense activities in space is contained in, for example, Trudy E. Bell, "America's Other Space Program," *The Sciences,* December "1979; Eberhard Rechtin, "Future Military Applications in Space," Speech to International Aerospace Symposium, Paris, June 1981; Thomas H. Karas, *Implications of Space Technology for* Strategic Nuclear *Competition,* Occasional Paper 25, The Stanley Foundation; J. Preston Layton, "Military Space in Transition, " *Aeronautics and Astronautics,* October 1981; the annual *Aeronautics and Space Report* of the President contains an approved description of national security space efforts.

Figure 10.—Historical Budget Summary-Budget Authority



ªT, Q. - Transitional Quarter.

SOURCE Office of Management and Budget

- **Earth observation.** –It was only in October 1978 that the existence of strategic surveillance satellites was officially acknowledged by an American President,[3] although the media and general public had assumed their existence for many years. Earth observation satellites are used to perform several different national security-related functions, including:
    1. early warning of missile attack;
    2. verification of compliance in related international arms-control agreements such as nuclear testing and strategic missile deployment; and
    3. surveillance of various areas of the world to gather data required for U.S. strategic and tactical planning.

  Military systems require degrees and kinds of performance not required for civilian purposes. Many different kinds of satellites and sensors are used to satisfy specific requirements. To the degree that military systems are more specialized and provide advanced performance, transfer of this technology to the civilian sector will continue to be an issue, especially as civilian needs become more specialized in turn.[4]
- **Communications.** –Although the bulk of routine military messages are carried over civilian-operated communication circuits, both terrestrial and satellite, there is also a variety of satellite communications systems available for the exclusive use of the military services and national command authorities. These military satellites are crucial links in the Nation's command, control, and communications systems; approximately one-third of U.S. long-distance military traffic goes by dedicated DOD satellites.

  A continuing problem in national security communications via satellite is how to

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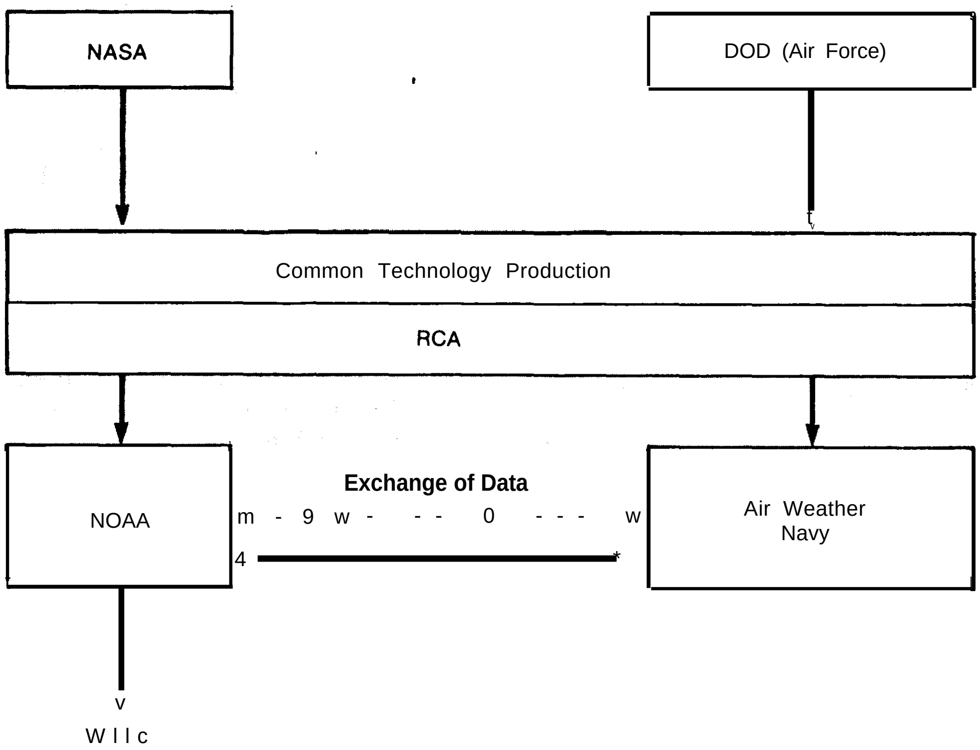
[3] President Carter gave public recognition to the existence of intelligence satellites during an Oct. 1, 1978 speech at the Kennedy Space Center.

[4] A pioneering analysis of the use of space systems for surveillance and warning is Philip Klass, *Secret Sentries in Space* (Random House, 1971); see also, "Study on the Implications of Establishing an International Satellite Monitoring Agency," prepared for the 2d U.N. Assembly Devoted to Disarmament, Aug. 6, 1981, pp. 15-18.

combine various existing and future systems into a coherent "architecture" which would allow the integrated use of communications capability by both civilian and military authorities under various crisis and conflict situations. At issue here is how dependent the military should be on nonmilitary communications channels and how much investment the military should make to ensure that civilian channels are survivable and secure under various conditions. For example, there has been substantial attention given to protecting the tracking and data relay satellites so that they can be used for defense as well as civilian purposes.

- ***Navigation.*** –There has been a long tradition in the United States of providing navigation services for both military and civilian uses; that tradition has been extended into the joint use of operational Navy navigation satellites. DOD's global positioning satellite (GPS) system, now in an advanced stage of development, will provide navigation assistance and position location for all military services, and will also be available for civilian use, albeit with somewhat degraded capabilities. Six Navstar satellites are now in orbit, with a total of 18 envisaged for the complete system.
- ***Meteorology.*** —The military operates its own weather satellites using technology rather similar to the National Oceanic and Atmospheric Administration (NOAA) satellites that serve civilian needs. There have been several analyses of the potential for combining civiiian and military meteorological satellite operations into a single system, but no such merger has been approved.
- Transportation. -The national security community has used the same launch vehicles,

Cooperation Between DOD and NASA in Meteorological Satellites



SOURCE: Office of Technology Assessment.

with certain variations, (except for the Saturn-class boosters used exclusively for manned Apollo launches) to boost its satellites into orbit as has the civilian space program (e.g., Atlas-Agena, Titan 11, Atlas-Centaur, Titan Ill). This pattern will continue with the shuttle. However, the military has separate checkout and launch facilities, both at Cape Canaveral and Vandenberg Air Force Base, for expendable launch vehicles, and is building a shuttle launch complex at Vandenberg. joint use of the shuttle implies joint use of mission control facilities at Johnson Space Center, though the Air Force is hoping to construct its own Consolidated Space Operations Center in Colorado Springs. There has been some suggestion of two separate shuttle fleets, one for civilian and one for national security use.

Future Developments

For the most part the systems discussed above support ground-, sea-, and air-based military operations and extend or enhance existing logistical capabilities. Under consideration now, however, are weapons systems that could operate in space. There is a vigorous science and technology development program oriented toward a wide range of future applications, including antisatellite systems and directed energy weapons. If the United States should decide to develop and deploy some sort of space-based, antisatellite or ballistic missile defense system, such an effort would require a major expansion of our space infrastructure, including the development of space platforms, space power systems, and space construction facilities. Pursuing such a course would imply major changes in strategic thinking, and thus a decision to develop space weapons systems is as much an issue of national policy as it is of technological potentials

Another area of future development is manned military space operations. Some see a need for manned observation, inspection, command and control, servicing, or other operations in Earth orbit. Military use of the shuttle will provide experience on which to base future decisions on the military role of man in space.

Large-scale development and deployment of manned and unmanned military systems in space, beyond those currently required for support purposes, will be based on decisions, not yet made, concerning military doctrine and national policy. The notion that space is a fourth theater of war which can supplement or supplant air, sea, and ground operations is not fully accepted by either the civilian or the military leadership of the national security community. Extensive manned military operations and/or weapons in space are still very much in the exploratory stage. In addition, current international treaties, such as the **1972** Anti-Ballistic Missile Treaty with the Soviet Union, as well as hopes for future arms-control agreements, may prevent or delay the deployment of space weaponry. There is a substantial degree of international concern, expressed at the United Nations (U. N.) and elsewhere, about any expansion of the arms race into outer space.

Civilian-National Security Relationships in Space: 1957-81

The decision to house defense-related space operations and the R&D leading to them within DOD and to create a new civilian agency for nondefense space research were made in the immediate wake of Sputnik, as the Eisenhower administration began to organize the U.S. space effort. These decisions were controversial; individuals both in and outside Government, particularly in Congress, the defense industry, and the military services, believed that the Nation should undertake a single integrated space program under military management.[6] However, President Eisenhower and the majority of Congress believed that there were significant advantages for the country in separating the national space effort into separate elements and in creating a separate man-

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[5] Rechtin, op. cit., pp. 7-8.

[6] The following account of the origins and early evolution of U.S. space policy and institutions is drawn from a number of sources including: John Logsdon, *The Future of the U.S. Space Program* (Praeger Publishers, 1975); Robert L. Roshlt, *An* Administrative *History of NASA, /953-1963*, NASA, 1966, and Enid Bok Schoettle, "The Establishment of NASA, " in Know/edge *of* Power: Essays *on* Science and Government, The Free Press, 1966.

agement and institutional structure for each element.

Similarly, President Kennedy rejected the notion, raised early in his administration, of combining NASA and Air Force space programs under military auspices. Like Eisenhower, Kennedy viewed the national space effort as having distinct civilian and military components, and decided to use the civilian space program as one of the major arenas for competition with the Soviet Union.

Early Policy Choices

Several factors influenced the decision by the Eisenhower administration and by Congress to establish a separate civilian space agency. One reason was the view of the scientific community that the major objectives of the civilian space program should be scientific in character, and that these objectives could best be met by a separate agency not linked to DOD programs. A more telling concern was Eisenhower's view that there were specific and positive benefits for the United States, in terms of both foreign policy and domestic politics, in creating an open space program under civilian control. These benefits were particularly evident, given that the Soviet space program was closed. The United States could claim that its civilian space program was an accurate reflection of the open, achievement-oriented character of American society, while at the same time developing whatever national security space systems were deemed necessary through a second, much less open program. Cooperation with other countries, desirable both to meet specific needs for access to sites for tracking stations, and to further general foreign policy goals, would be greatly facilitated by such a separation.

At the policy level, Eisenhower and his top advisors did not deal with military and civilian space efforts in isolation, but rather viewed them as parts of a single national space program. Eisenhower authorized DOD to undertake whatever military space efforts could be justified by existing and future military requirements, but he did not approve the futuristic plans generated within the Air Force (such as a manned Moon-base) and the Army. Nor did he approve ambitious NASA plans for the 1960's. There were attempts to develop a comprehensive national space policy under NSC auspices. The objective of such a policy was the development and exploitation of U.S. outer space capabilities to achieve scientific, military, and political goals, and to establish the United States as a recognized leader in this field. However, Eisenhower and his advisors did not believe that the political returns from space achievement were large enough to merit a major investment of resources, and thus were unwilling to approve an aggressive civilian space program aimed at political objectives.

President Kennedy was willing to approve such a program, however, and, in Apollo, the United States undertook an enterprise justified primarily by national prestige and political payoff.[7] The policy that led to the Apollo commitment was formulated in the context of developing an integrated national space policy. Apollo was the centerpiece of an across-the-board acceleration of both civilian and military space programs, aimed at achieving U.S. preeminence in all areas of space technology. Kennedy was told that "the nonmilitary, noncommercial, nonscientific but civilian projects such as lunar and planetary exploration are . . . part of the battle along the fluid front of the Cold War."[8]

While Presidents Eisenhower and Kennedy both desired a national space program in consonance with overall national policy objectives, one which maximized returns on both the civilian and military investments of national resources, coordination of the two programs was not a straightforward matter. During the 1960's the civilian space program, and particularly its central activity, Apollo, developed in ways that made close interactions with major defense space applications difficult. Although NASA did maintain Earth-oriented science and applications programs, its major manned and unmanned efforts such as Apollo and planetary exploration were oriented outward, away from Earth. Though there were attempts to undertake joint planning for tracking stations, meteorological satellites, and

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[7] A full account of the Apollo decision is contained in Logsdon, op. cit.

[8] Ibid., p. 126.

geodetic satellites, none of these resulted in closely integrated civilian-military activities. The exception was in the area of launch vehicles. NASA used the Atlas, developed by the Air Force, for its Mercury program and the Air Force developed Titan for the Gemini program. In fact, with the exception of Saturn, which was used only for NASA's Apollo program, launch vehicles for all these manned satellites were shared; DOD had no use for such a large and expensive launch vehicle as Saturn. As DOD requirements for some launch vechicles, such as the Thor and Atlas, decreased, these were transferred to NASA.

In particular, the decision to accomplish Apollo by means of lunar-orbit rendezvous (LOR) was a watershed in separating civilian and military manned space flight programs for almost a decade.[9] There was extensive controversy preceding the decision for LOR. Many argued that if Earth-orbit rendezvous were used to accomplish Apollo, the knowledge gained from rendezvous of spacecraft and assembly of structurs in low-Earth orbit would be valuable not only for the lunar program, but also for national security activities. However, NASA, driven by a desire to meet the lunar landing goal before 1970, chose LOR as the method most likely to make this achievement possible. This choice, in addition to NASA's emphasis on planetary exploration in its unmanned scientific programs, to a large degree separated the central element of the NASA program from national security space efforts during the 1960's and early 1970's.

Program Relationships in the Early Years

The NAS Act, which provided for separate civilian and national security space programs, also called for "close cooperation among all interested agencies of the United States in order to avoid unnecessary duplication of effort, facilities, and equipment. " As this directive was carried out, there were substantial interactions between civilian and national security space efforts during the first decade of the national space program, even though NASA had set its sights on the Moon. At the project and program levels, these interactions were on balance cooperative and productive. However, at the policy and institutional level there were, perhaps inevitably, stresses between separate programs in the same technological arena. It is beyond the scope of this assessment to detail these interactions, but the following brief summary may provide some sense of their character.[10]

MANNED SPACE FLIGHT

It was the armed services that during the 1950's did the first detailed planning for manned space flight, but NASA was assigned the U.S. manned mission in 1958. Project Mercury was based on Air Force plans, and the Air Force was left with only a modest, and never fully funded, space glider program (Dyna-Soar), which was eventually canceled. At one point the Air Force contemplated a "Blue Gemini" program using NASA's Gemini vehicles; when NASA balked, DOD settled for a modest series of experiments on Gemini flights. Late in 1963, Defense Secretary McNamara approved the Manned Orbital Laboratory program for the Air Force. This program was terminated in 1969 because foreseeable military requirements were inadequate to justify it, despite the $1.3 billion already spent. Since that time NASA has had complete responsibility for the manned flight portion of the national space program, although this situation will change when the shuttle begins to fly missions dedicated to national security.

LAUNCH VEHICLE DEVELOPMENT

Immediately after the acceleration of the U.S. space program in 1961, there was an intensive attempt to integrate future launch vehicle developments. This attempt was not successful, and NASA went on to develop Saturn boosters for Apollo missions while DOD added the Titan III as the heavy-duty launcher for military and intelligence programs. When it came time to consider whether to continue to use Saturn as the workhorse for the post-Apollo civilian space pro-

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[9] **John M. Logsdon, "Selecting the Way to the Moon: the Choice of the Lunar Orbital Rendezvous Mode, " Aerospace Historian, June 1971, contains an account of this decision.**

[10] An account of early NASA-DOD **relationships is** contained in W. Fred Boone, *NASA Office of Defense Affairs: The First Five Years,* **NASA Historical Note HHR-32, 1970.**

gram or to develop a new type of reusable launch vehicle, the policy was made in an explicit context of joint civilian-national security requirements, although the development task was assigned to NASA. That the shuttle would be a multiuse launch vehicle with its design suited to meet defense and intelligence requirements as well as civilian needs was essential to the program's approval. ’ [1],

COMMUNICATIONS SATELLITES

Originally, NASA was assigned responsibility for developing passive communications satellite technology (e.g., Echo), whereas DOD developed active communications satellites. There was an early shift in this division of labor, and NASA by 1960 had begun to develop active communications satellites for civilian use. With the cancellation of the Army's ADVENT geosynchronous satellite program due to technical and management problems, it was left to NASA to develop geosynchronous communications satellites, which have proved to be the key to both civilian and military satellite communications efforts. During the 1960's and 1970's both NASA and DOD had active R&D programs investigating communications satellite technology appropriate to differing civilian and military requirements.

METEOROLOGICAL SATELLITES

DOD sponsored the initial research on meteorological satellites; this work led to the TIROS program, which was transferred to NASA and then became the basis for the first operational civilian weather satellite. DOD used the same contractor to develop weather satellites dedicated to military uses. The result has been the existence of two systems which, while using the same "bus" contain different sensors and fly in different orbits, and a continuing controversy over the need for separate weather satellite systems.

EARTH OBSERVATION PROGRAMS

The advantages of the view from outer space for strategic surveillance were obvious from the beginning, and DOD and various intelligence agencies began highly classified Earth observation programs. As the sensors developed for these early national security programs (e.g., the Return Beam Vidicon) were supplanted by more advanced models, some of them were declassified and became part of NASA's civilian remote sensing experiments in the late 1960's. There has been a continuing tension between the desire to maintain maximum secrecy about the capabilities of U.S. surveillance systems and the desire to use both the products of those systems and the components developed for them for operational civilian applications systems.

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[11] Jerry Grey, *Enterprise* (Morrow, 1979), pp. 66-68.

CURRENT POLICY AND POLICY REVIEW PROCESS

Policy Formulation and Program Stresses in the Post-Apollo Period

Carrying out the Apollo commitment kept NASA fully occupied during the 1960's, and for the most part relations between the civilian and national security space programs were conducted on a case-by-case basis, mainly at the project and technology level. Only occasionally, as in the controversy over control of Gemini and post-Apollo manned programs, did the tensions rise to the policy and institutional level. The major channel for interaction was the Aeronautics and Astronautics Coordinating Board (AACB), a joint NASA-DOD body. NASA also established an Office of Defense Affairs, which was active in maintaining liaison with defense and intelligence space efforts. Tensions rarely escalated to a level at which White House policy offices such as the National Aeronautics and Space Council and the Office of Science and Technology got involved in their resolution.

During the past decade, however, there have been several Presidential-level policy reviews of the national space effort that have dealt with civilian and national security programs in a common framework. Perhaps the basic point to be made about these reviews is that each examined and revalidated the policy that civilian, military, and intelligence programs should be carried out in separate institutional frameworks, although each review also recognized opportunities for closer cooperation and coordination among these separate programs.

The first such comprehensive review was carried out during the summer of 1969 under the auspices of a Space Task Group (STG), created ad hoc and chaired by the Vice President. (The deliberations of the STG are described in some detail inch. 5.) President Nixon charged STG with providing him a "definitive recommendation on the direction the national space program should take in the post-Apollo period. "[12] The review considered future directions of both the civilian and military space programs, but its focus was on the future for the civilian manned program. A major and lasting result of STG'S review was the concept of a reusable space shuttle to serve almost all national launch vehicle requirements, from commercial uses to intelligence missions. To realize this concept, technical characteristics, as well as managerial and funding patterns, were negotiated by NASA and DOD (represented primarily by the Air Force). As has become evident since the 1969-72 period, the interagency planning did not resolve all of the program issues that have subsequently caused continuing NASA-DOD tension over the shuttle program.[13]

By 1977, enough stresses had built up among the civilian, military, and intelligence space programs that president Carter authorized a Presidential-level space policy review. **The stated purpose of the review** was "to resolve potential conflicts among the various space program sectors and to recommend coherent space principles and national space policy."[14]

Recent Policy Reviews

The Carter administration adopted the NSC policy review process as the primary mechanism for considering and developing space policy, both civilian and military. The initial review was carried out under the guidance of Presidential Review Memorandum 23, which considered questions about civilian-military relationships and resulted in Presidential Directive 37 (PD/NSC-37). This review was followed by further interagency review requested by the president in June 1978, which led to a second Presidential Directive (PD/NSC-42) and a public announcement on U.S. civilian space policy in October 1978. In this statement, President Carter identified decisions that were designed to set the direction of U.S. efforts in space over the next decade. Among other things, the announced civilian space policy was to promote a balance of applications, science, and technology development that would "increase benefits for resources expended through better integration and technology transfer among the national space programs and by using more joint projects when appropriate. "

As part of the Presidential review several decisions were made in specific applications areas, either as program guidance or for the conduct of further studies.

- NASA was to chair an interagency task force to examine options for incorporating current and future remote-sensing systems into an integrated national system, with emphasis on defining and meeting user requirements.
- The Defense community, NASA, and NOAA were to conduct a review of meteorological programs to determine the degree to which these programs might be consolidated in the 1980's and the extent to which separate programs supporting specialized defense needs should be maintained. The possibility for integrated systems for ocean observations from space was also to be examined.
- With respect to technology sharing, steps were to "be taken to facilitate technology transfer between the space sectors. The objective was to maximize efficient utilization of the technologies while maintaining necessary security and management relationships.

In November 1979, president Carter approved further civilian space policy that amplified the policies established in PDs 37 and 42. The new

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[12] The space Task Group was established by a Feb. 13,1969, memorandum from the President.

[13] Edgar Ulsamer, "Space Shuttle Mired in Bureaucratic Feud," Air *Force,* September 1980.

[14] The unclassified version of the results of the review of space policy was issued in the form of a White House press release on June 20, 1978.

policies were contained in Presidential Directive/NSC-54.

The policy decisions in PD-54 were the result of extended interagency debate, and were based, in part, on the results of the various studies and reviews mandated by PD-42.

PD-54 directed that DOD and the Department of Commerce (DOC) maintain and coordinate dual polar-orbiting meteorological programs, with each continuing to procure systems and operate separate satellites to meet the differing needs of the military and civilian sectors. When new polar-orbiting satellites became justifiable they were to be jointly developed and procured by DOD, DOC, and NASA in order to maximize technology sharing and minimize cost. An "appropriate" coordination mechanism was to be established to assure effective cooperation and to prevent duplication.

For oceanic programs, PD-54 further stated that if oceanographic satellites were to be developed, DOD, DOC, and NASA were to pursue joint development, acquisition, and management. A committee was to be established with expanded representation to forward recommendations on policy issues to the policy review committees in NSC for consideration and actions.

The classified character of the basic documents, accentuated by the use of NSC as the forum for discussion, has made congressional and public discussion difficult. This has been a continuing problem in raising and resolving many issues of civilian-military relationships.

Current Administration Policy Review

The various policy reviews of the 1977-79 period continue to provide the formal underpinning and guidance that govern today's programs in both civilian and military applications. However, the Reagan administration has initiated a broad examination of the extant policy. Although strongly driven by the administration's perceived need to constrain the Federal budget, the review is intended to be comprehensive, and will include an examination of the provisions of the NAS Act. The review will focus on the use of the space transportation system for civilian and national security purposes and on commercialization of civilian Earth observation systems.

The President's science adviser has undertaken the review, which will be coordinated via a "Cabinet Council" mechanism. The Policy Review Committee (Space) of the Carter administration has now been disbanded. There are new pressures on several fronts. The administration's budget cuts have necessitated a wholesale reevaluation of many planned civilian space program initiatives in applications and also in space sciences. In addition, the success of the shuttle has introduced the need to focus on civilian-military relationships at a new level of detail.

CURRENT INSTITUTIONAL AND PROGRAMMATIC CHARACTERISTICS OF CIVILIAN AND NATIONAL SECURITY SPACE EFFORTS

The possibility and desirability of closer civilian-national security relationships in space depend on the strengths and weaknesses of the current structure and the differences and similarities between the two areas of space activity. Although the two programs have certain common interests and a history of cooperating to solve common problems, their different goals and consequent divergence in evolution have resulted in different institutional and program characteristics. These are reviewed below.

Mission Differences

NASA is an R&D agency with its primary mission the development and demonstration of space and aeronautics systems and associated technology, the provision of launch services, and the operation of research and scientific satellites. NASA has a tradition of evaluating the potential of space technology in a broad societal context with a long time horizon. NASA's R&D efforts are linked to the requirements of various users, but its **strongest tendency is towards development of new technologies rather than meeting short-term needs** of users. Civilian missions require the collaboration of the widest possible body of users to help share and justify the very large front-end costs of space systems. For example, the design of civilian remote sensing systems has been affected by the need to resolve the data requirements of a multitude of civilian missions and to determine a fair allocation of costs. Conflicts among agencies over instrument selection, system characteristics, and technical tradeoffs will continue to plague the Government-sponsored growth of operational systems.

DOD's space activities, by contrast, have some characteristics of technology push, but they are primarily responsive to the requirements of military operations. DOD has a clear and vital mission, national defense, and space technology is seen as one means, among others, for accomplishing it. The military users of space technology are within DOD, and the problems of transfer from developer to user are fewer than if the two were in separate organizations. DOD has been considering possible changes in management that would reflect the military's increased dependence on space systems and allow for efficient use of the space shuttle. These include establishing a separate Space Command, either in the Air Force, or as a fourth service.

In congressional testimony early in **1981, the Secretary of the Air Force identified an order of priority for the various program activities that the Air Force conducts in space.**

- **First priority** was given to the maintenance and development of a reliable and satisfactory launch vehicle capability. Employing the shuttle to maximum advantage for missions related to national security and protecting against possible delays and failures in the shuttle program were considered vital.
- Second priority was given to surveillance and warning satellites. These functions generally cannot be performed by alternate ground-based facilities.
- Third priority was assigned to satellites related to communications. Though communications satellites are important, alternate ground-based means of communications (undersea cables, short-wave) are usually available.
- Fourth priority went to weather observation and navigation. Because other means exist to carry out their tasks, they are lower in priority than other satellite systems.

Openness v. Need for Secrecy

The NAS Act mandates, among other things, that NASA provide for the " . . . widest practicable and appropriate dissemination of information concerning its activities and the results thereof. " The specific provision to make information available to the public contrasts sharply with the information policies governing classified military and intelligence programs, which operate under stringent requirements to protect information, including even the fact that some of the programs exist.

The differences in orientation between the civilian and military programs have been maintained from the beginning of the programs to the present and are fundamental to consideration of policies on technology sharing and other interjector relationships.

- There are inherent conflicts between the need for secrecy in national security programs, and the free exchange of data characteristic of the civilian space program. These conflicts extend into the project office, where secrecy requirements imposed on sensitive national security projects are a continuing fact-of-life, though they are essentially nonexistent on the civilian side.
- For technology sharing, these differences generate a basically asymmetrical relationship. Activities or technology in the civilian sector are examined in detail for potential national security uses. The reverse does not hold except through specific interagency mechanisms that have been formed to promote information exchange. Even with information exchange, the civilian community rarely has an opportunity to affect national security planning. The reverse is less true. **National security planning may often affect civilian programs.**

- Military and intelligence missions normally enjoy a high relative priority within the Government. This is reinforced by the secrecy surrounding such programs, making it dificult for most members of the Executive, of Congress, and the public to criticize them effectively or to bargain for increased attention to and funding for civilian activities. The result is that the military or national security program can seek out or develop new technology to aid in accomplishing their missions, using the full range of classified and unclassified experience, whereas civilian programs have definite limits set on use of sensitive or classified technology.
- in some cases, not only technical details of military or intelligence space systems, but even the fact that such a system exists may be classified. This creates a special burden upon the program managers and the contractor teams, and makes it very difficult to carry out technology-sharing activities with other programs. The precautions that may be necessary to protect the "fact of" a certain system would act as a significant deterrent to the ability of the classified program team to volunteer its assistance.

Differences in the Institutional Support Base

At NASA's founding, it incorporated the National Advisory Committee on Aeronautics, its technical centers, and a number of DOD activities such as the Army Ballistic Missile Group in Huntsville, Ala., and the Jet Propulsion Laboratory in pasadena, Calif. Thus, NASA inherited an infrastructure of Government-owned facilities and supporting technical staffs that were already familiar with all phases of the agency's projects, from early definition to the production and test of flight hardware. When NASA expanded to meet the demands of Apollo and other new program activities in the early 1960's, it elaborated the pattern of relatively autonomous technical centers (see ch. 9). NASA's technical personnel and specialized facilities represent a unique national resource, developed at great cost and representing over 20 years of experience in designing and operating successful space systems.

DOD's role in operating the military and national security programs, on the other hand, evolved very differently. Although encompassing an extensively laboratory structure, DOD moved away from the "arsenal approach" of in-house technical laboratories in the years following World War II. The process of developing ballistic missiles, the prototype for DOD's space effort, followed a pattern in which a Government project team of civilian and military personnel acted as overall managers for a private contractor team; one major contractor acted as system integrator. This pattern persists today. Technical assistance for specific parts of the system is often obtained from government laboratories, but the laboratories typically do not undertake management. Practically the entire DOD space program management is vested in the Air Force Space Division, a part of the Air Force Systems Command. This Space Division is supported by the Aerospace Corp. as system engineers. Thus, whereas NASA development management activities are done largely at separate centers, DOD activities are centralized. The Space Division has responsibilities equivalent to those of NASA in that it is responsible for all procurement, launch, and on-orbit control and recovery. Generally, when a satellite system becomes operational, the mission aspects of the satellite system come under the control of a user command, say Strategic Air Command or Defense Communications Agency, while the Space DiviSion maintains control of other aspects of the satellite system including replacements. The Space Division can and does call on other DOD agencies and laboratories. The Space Division has direct control of the launch facilities at the Eastern Test Range at Cape Canaveral and the Western Test Range at Vandenberg AFB.

Thus, in both the civilian and military space programs, a great deal of the national capability resides in the contractors, and to the extent that a single contractor may support both programs, significant technology transfer occurs, without documentation and without the need for specific efforts. Within NASA, programs are largely developed and managed by the centers, and any consideration of technology sharing or closer institutional relations between NASA and DOD needs to take into account these differences in the two programs.

International Aspects

International cooperation was one of the objectives set for NASA in 1958, and the United States has pursued an extensive cooperative program with technical, economic, and political benefits. Although certain foreign countries participate in some DOD space activities, their participation is based on joint defense objectives; its character is quite different, from NASA's international activities.

There would likely be tension between security requirements and any extensive interaction between other countries and the United States in civilian space efforts if there were a much closer civilian-military relationship. Some of these tensions are already evident as the military and non-U.S. users both plan to use the shuttle. Scientists in foreign countries might also be less willing to deal with a U.S. space program closely linked to national security activities.

The relationship between the civilian and military space programs is affected by the presence or absence of treaties, laws, and rules of conduct governing activities in the "international commons" of outer space—i.e., by the entire international legal framework. During the 1960's precedents were set that strengthened the U.S. position that governments could carry on nonthreatening activities constrained only by the prohibition in the 1967 "Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space" on weapons of mass destruction. The SALT I agreements in 1972 further recognized that there were "national technical means of verification" (presumably overhead reconnaissance by spacecraft) and that such collection devices should not be interfered with. Civilian remote sensing systems such as Landsat and meteorological satellites have also operated on a global basis without restriction; partly to forestall criticism, the United States has made data from these systems available to all countries. The emergence of significant programs by France, Japan, and others during the 1980's may complicate the existing ground rules and put additional pressure on the United States to maintain open programs conducted in cooperation with other nations, particularly with less developed countries. Current discussion in the U.N. and elsewhere about restricting the gathering and dissemination of civilian data should not be expected to affect U.S. military satellites.

An additional factor that may drive the U.S. space program to emphasize international visibility and accessibility would be the need to respond, for practical political considerations, to a newly emerging Soviet presence in peaceful space applications. The Soviets are known to have carried out an ambitious program of launching and recovering film camera satellites with high-resolution data. The lag by the U.S.S.R. in critical areas of technology, particularly computers, has until recently caused the Soviets to say little about their space applications programs while playing up manned space flight activities. However, the Soviets recently issued an important paper to the U. N.* that describes their applications programs in greater detail than previously available (described in detail in ch. 7). In particular, the Soviets claimed to be planning a "quick-look" sensing system with several types of multispectral sensors. Mindful of the tremendous impact of Sputnik, 25 years ago, forums such as the upcoming U.N. conference, UN ISPACE '82, to be held in Vienna in August 1982, may well provide the occasion for the Soviets to announce plans to make their data available to other countries.

Common Civilian-National Security Needs and Cooperative Activities

Many of the problems faced by both civilian and national security space programs have common roots in the inescapable realities of the harsh space environment and the stringent requirements associated with launching payloads into space. In the early stages both the civilian and military space programs depended on using the most suitable military systems. Improving their reliability was an early and important common task for both civilian and military authorities. As a result, a wide range of basic system details were shared. They included rocket engine design,

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structures, electronics, guidance, control systems, and a variety of subsystems.

Both programs have common needs for ground launch complexes with adequate instrumentation for prelaunch, launch, and postlaunch monitoring and control of satellites and vehicles, and launch safety and tracking. These common needs have resulted in highly integrated operations at both Vandenberg AFB (polar orbit and high inclination launches) and at Kennedy Space Center (low inclination, deep space, and synchronous orbit launches).

There is also a continuing common need for better understanding of outer space. This includes scientific observations of electromagnetic radiation at all wavelengths, the characteristics of solar radiation, studies of the Earth's atmosphere and its attenuation, propagation and reflection characteristics, and variations in gravitational effects. Beyond these basic common needs, some civilian and national security programs, such as those for meteorology and communications, have very similar technical characteristics.

Combining programs that provide specific types of information, such as the weather data, has been an attractive but difficult goal. Meteorological data is valuable principally if it is put in the hands of users as rapidly as possible, and conflicting demands for data between customers may mean that one set of users will be slighted if the system is less than sufficient for total coverage. Military needs for aircraft operations, for example, may constrain the satellite's orbital timing and type of data gathered in ways incompatible with civilian weather forecasting.

In collecting observational data of the Earth, the civilian community has information needs that are both identical to and quite separate from those of the military. Both communities have quite similar requirements for medium-scale maps. However, the military need for intelligence requires high resolutions not needed for most civilian programs. As civilian programs have matured, additional resolution and spectrum needs have caused some convergence of technical requirements, which further complicates the task of preserving the security of the DOD-operated systems while improving the capability of systems used for civilian operations. An example of the difficulties encountered in implementing joint systems is the National Oceanographic Satellite System (NOSS) (for description see pp. 50-51).

ISSUES AND POLICY OPTIONS

Technology Transfer

Inherent in the establishment of separate national space programs has been concern for effective "technology transfer" among different activities and agencies. In many cases costly technologies developed to meet the objectives of one space program may have direct utility for other programs. Sharing hardware and expertise can avoid unnecessary duplication of effort, save scarce financial, technical, and human resources, and enhance program capabilities.

In considering technology transfer, one must distinguish ***space-related*** technology (launch vehicles and facilities for guidance, command, and control of launchers and satellites) from ***applications-related*** technology (sensor systems, communication equipment, data collection, and processing technologies). A special result of applications technology is the data themselves (e.g., remote-sensing images), which can be shared without transferring the technology used to gather or process them. in general, space-related technology has been more easily transferred, because it is less sensitive and less specialized than applications technologies.

Technology can be transferred either from civilian to military/national-security (MNS) programs, or vice versa. Substantially different issues arise depending on the direction and type of technology involved. In general there are few if any restrictions placed on the transfer of civilian or NASA-developed technology to MNS programs. Problems arise when classified technology or data appears to be of use to the civilian sector.

- Transfers to the civilian sector of space-***related*** technology developed for the military are relatively direct and open for unclassified programs and technology, but involve additional controls and supervision when there are classification considerations that affect the MNS programs. In practice, there is considerable sharing of military space-related technology between the sectors.
- By far the most complex and difficult relationships to manage are those involving the transfer of ***applications-related*** technology from the military/national security sector to the civilian sector. Since the national security applications are highly sensitive, there are necessarily strict limitations on access to technical information, even to evaluate its potential usefulness for civilian purposes.

The key to effective transfer is to combine awareness of different programs at the policy and administrative level, to exchange information at the technical level, and to agree on joint responsibilities:

- The easiest transfers to implement are those that involve the direct use by a private contractor of technology developed in a classified program to meet similar needs in another. This situation allows a lower bid to be made, and enables the contractor to assure adherence to costs and schedules. Since contractors cannot themselves approve the transfer of classified technology, the Government must take the lead in facilitating such actions, even though the same personnel and facilities may be used by the firm involved,
- Procedures for transfer are most complex when a classified technology is suitable for a civilian program but no channels have been established for the two programs to interact. Frequently, no direct interface between classified and unclassified programs, or even between separate classified activities, is allowed at many technical and managerial levels.

The objective of technology sharing or transfer arrangements is to ensure that the broadest use is made of available technology and that national resources are not wasted through unnecessary duplication of effort. The condition governing such transfers is that disclosure of the technology not reduce the effectiveness of a program or project, or harm national security.

There are several factors that impede the technology transfer process at the program-management level. There are few internal incentives to transfer technology to other programs; from the point of view of national security program managers, transfer to civilians may compromise security and tie up valuable time, money, and manpower in conducting and supervising the transfer. Unless there is a clear quid pro quo in the form of additional resources or the prospect of future aid from the civilian program, technology transfer will have low internal priority.

The competitiveness of the aerospace industry in part offsets the reluctance to share information and expertise. Competitiveness works in two major ways. In the first place, it causes new proprietary technology to be developed to improve products and sales potential across the space sectors. ***In*** the second place, the competitive bidding for Government work promotes technology sharing because using an existing technology is less costly in time and resources than developing a new one. These factors provide an incentive for both Government and industry to consider existing technology and hardware in the development of system requirements, specifications, and design approaches. Additionally, even if a complete system such as a space vehicle may be classified, technology sharing of many unclassified subsystems or component technologies may be possible.

In practice, there is a continuing exchange of data and viewpoints between programs in the several sectors at both formal and informal levels. in many instances informal exchanges and discussions are preferred over formal, because of lower visibility and the greater flexibility afforded by the absence of formal arrangements and their related institutional/bureaucratic implications. Without access to classified information it is impossible to evaluate the overall efficiency of these relationships.

Technology transfer is further enhanced in those situations when a common contractor base is involved across sectors, or when personnel from one sector and technology are able to move to similar or related functions in other sectors. A good example of the latter has been active or retired military personnel working with NASA.

In addition to various informal and intra-industry mechanisms for technology transfer or sharing, there is a formal body to coordinate between NASA, DOD, and AACB. AACB is the highest level formal coordinating mechanism between DOD and NASA. By a 1960 interagency agreement, the responsibilities of AACB included:

- planning of NASA and DOD activities to avoid undesirable duplication and to achieve efficient utilization of resources;
- coordination of activities of common interest;
- identification of problems requiring solution by either NASA or DOD; and
- exchange of information between NASA and DOD.

AACB is cochaired by the Deputy Administrator of NASA and the Director of Defense Research and Engineering (DDR&E) of DOD. Both of these are policy-level officials. AACB has panels to deal with issues that arise in several main areas. AACB is concerned primarily with defining broad policies rather than working out detailed arrangements for cooperative activities. Technical details have generally been coordinated by special interagency committees or working groups organized for those purposes. Many joint NASA/DOD subpanels and committees, which report to AACB panels, have been established to assist interaction. There are also many individually negotiated agreements and understandings.

Security Classification Barriers

Civilian access to classified technology is inevitably limited. As defined in executive orders that establish the rules for security classification, there are specified levels of potential damage to the national security that must exist before security classification and controls can be imposed. When such conditions exist, the relevant information is classified at its appropriate level and restricted to those individuals possessing the requisite clearances and “need-to-know.”

Because the effectiveness of a national security program may depend on the security protection of key attributes, there are many legitimate incentives for managers of classified programs severely to limit knowledge or access by personnel who have secondary, as opposed to primary, reasons for program involvement. Technology sharing inevitably falls in the “secondary” category. On the civilian side there are incentives to remain free from the restrictions and encumbrances that classification and security controls require. Sharing classified sector technology with programs in the civilian sector, therefore, has disincentives on both sides. It is warranted only when it can be established that there are sufficient benefits and savings to civilian programs to justify the transfer, given additional program costs and potential security risk.

Interagency Government mechanisms have been established that provide for selected civilian personnel to be cleared in order to have access to sensitive programs and related technology. Because of the security considerations and “need to know” criteria, the number of such personnel is kept as low as is judged feasible, to discharge technology transfer or other coordination objectives. The few cleared civilian agency personnel are responsible for knowing the entire range of civilian interests in their field and for identifying the potential match between civilian program needs and the classified system technology. When the civilian need occurs, an evaluation is made of the potential benefit in relation to the security risk of release. Though in practice there is wide variation, the relationship between classified and unclassified programs cannot fail to be unbalanced. Personnel working in classified programs can readily learn about technologies under development in unclassified programs, but the reverse does not hold. A security concern at the margin will almost always outweigh an otherwise equivalent civilian benefit.

There are long-standing controversies concerning the security classification programs of the Government. The issues have not been ***whether*** there should be classification, but how to provide appropriate levels of security protection for necessary programs without abuses and without undue shielding of Government activities from public scrutiny. Because determinations of whether given entities are to be classified and if so, to what degree, are necessarily made by members of the national security community (under guidelines established by the President as Commander-in-Chief), whose primary responsibility is to protect national security, not to foster civilian applications, there is an inevitable tendency to "play it safe" by stringently classifying all sensitive materials.

Persons who have had experience in both civilian and national security programs acknowledge that there are instances of failure, but also note successes in technology transfer; given the inherent difficulties, they generally argue that the processes are as good as it is reasonable to expect within current policy guidelines.

The uneven relationship between national security and civilian interests is frustrating, primarily to personnel in the civilian sector. They distrust the capabilities and incentives of classified program managers to evaluate the potential for civilian uses of technology developed in classified programs. Civilian sector personnel are not in a position to "browse" through classified technology, or to pursue ideas or insights generated in the normal course of engineering or scientific endeavors. Civilian frustration is particularly acute when independent civilian investigation leads to, or stumbles onto, technology that has already been classified or is then placed under security restrictions.

Within the executive branch, interagency boards and mechanisms charged with exchanging information and coordinating implementation of policy guidelines provide oversight of transfer processes. Congressional oversight is provided through the Select Committees on Intelligence and the various committees that oversee the civilian and other military space programs. An entirely new dimension will be brought into being if significant operational space systems are developed and operated by private commercial firms.

Additional problems arise from the existence of various levels of security controls within the classification scheme, whereby those privy to certain kinds of information may not have access to other parts or to the whole. Internal Government reviews have been carried out periodically to reexamine: 1) the need to provide continuing protection for specific classified systems, technology, and data, and 2) the degree of protection that may be required. Oversight is provided by properly cleared congressional committees and staff. Because the congressional oversight function extends to many other aspects of the DOD-operated space program, there is need **for continuing review of security classifications** in order to ease barriers to technology transfer and to the broader use of data from DOD-operated systems.

Interagency Review Mechanisms

The current practice of permitting access to a limited number of key individual from NASA and other civilian agencies with a need to know about the nature and capabilities of classified systems provides an initial indication of what is available and what is possible. The subsequent steps, leading to detailed understanding of the classified system and its components, and relating this understanding to the possible civilian setting in which the technology might be used, are all dependent on this initial, survey-type exposure to the classified systems. Therefore, it is incumbent on DOD (and other national security entities) to **continue the practice of clearing individuals at various levels in the civilian user agencies and to provide them with periodic briefings on classified systems and technologies.** it is equally necessary for agencies with a need for such information **to select individuals for access to highly classified information who are capable of making broad judgments about the desirability of technology transfer.** Individuals at the policy level as well as at the technical and managerial levels are needed in order to cover the various aspects of the agencies' needs.

The next steps in the transfer process call for more detailed knowledge of the technology and a degree of individual specialization that will vary greatly depending on the nature of the technology. At this level, quite often an expanded set of cleared people is required from the civilian agency, with a very narrow focus on the specifics of the system or subsystem involved. This degree of access will depend on a determination that the technology in question can be transferred without compromise. This determination inevitably is made by DOD or another national security agency. If a decision is made that a technology (or piece of hardware) may not be transferred, an appeal may be made up to the management level at AACB. Further appeal would require referral to an interagency forum at the White House level, usually via the NSC mechanism. Because of the special clearances required for the discussions in such a'forum, the NSC mechanism is well suited for this purpose. Alternatively, the "mechanisms for consensus" discussed in this report could also serve as the interagency forum, with properly cleared representatives from the agencies involved.

It should be emphasized that there is no indication that there has been arbitrary or capricious application of the security barriers to preclude civilian use of military technology. The central fact is that national security authorities have little incentive to press for greater access or use of their technology, systems, or data. Such broadened access is potentially threatening because of the loss of control it implies—the prospect that more information is being released than is desirable. These legitimate concerns are not readily dismissed, nor can they be easily tested by the civilian agencies. Thus, the interagency mechanism needs a "third party" such as the NSC staff, the Science Adviser, or perhaps the Vice President, to ensure that such questions receive balanced consideration. Congress can play an important role through hearings, oversight, and explicit incentives, both in uncovering the scope of the problems and in resolving them.

Future of the Space Shuttle System

The shuttle program represents the largest current area of interaction between the civilian and military space sectors, and it will be the continuing focus for many of the civilian-military policy issues in the period immediately ahead. The shuttle will be central to both the civilian and military space programs.

From the beginning of consideration of the shuttle, the Air Force worked closely with NASA to incorporate defense requirements into the vehicle. Formal coordinating mechanisms were established, with AACB serving continuously as the mechanism for coordinating formal policy at the highest level. The Presidential decision on the shuitle in 1972 directed it to serve all users, civilian and military. This decision entailed development of a vehicle that would integrate civilian and military requirements, and military requirements had a significant bearing on many of its design specifications.

NASA has borne most of the development funding for the shuttle, rather than sharing this responsibility with DOD. The initial plan was to limit the Air Force to building and operating the Vandenberg shuttle launch and landing facility, and to paying for operating costs for DOD missions. The Air Force later assumed development responsibility for the inertial upper stage.

The rationale for NASA's lead role in funding and management has been that sharing between the two organizations would complicate the management of an already difficult and challenging program and drive up the program's total costs, and that NASA was better equipped to design and oversee manned systems than DOD. A formal NASA/DOD memorandum of understanding (MOU) on management of the space transportation system was signed in early 1977, and revised in early 1980. The basic MOU establishes the broad policies; there are additional agreements and MOUS on specific aspects of the program.

A major problem with this arrangement is that NASA has had to cut other programs to pay for shuttle overruns. Given DOD's much larger budget, it has been argued that the Air Force should shoulder some of the shuttle costs; the Air Foce has resisted in order to avoid being put in a budget situation similar to NASA'S. An arrangement to "fence off" the shuttle budget so that it competes with other national programs, and not with either agency's continuing projects, would help to alleviate many tensions between NASA and DOD.

At the present time, interaction between NASA and DOD elements proceeds at all management levels, with active coordination on a daily basis. Inevitably, there has been a continuing series of strains and issues that stem from differences in basic mission and outlook between the two organizations. Many decisions must be made by

NASA without the opportunity for total coordination with all parties of interest, including DOD.

Operations of the space shuttle bring civilian and DOD-operated payloads into the same stream of activities, from prelaunch preparations through recovery and postlaunch processing, with the result that special provisions must be made to ensure that adequate protection is provided to sensitive information and systems. When examined in detail, the transportation system cannot be divorced from its payloads. Every payload entails specific operating characteristics that then become subject to some of the same controls that exist for the compartmented classified systems. Given this added complexity, many have suggested that separate shuttle orbiters uniquely configured for DOD launches would be preferable to joint facilities, and that DOD ought to operate a separate shuttle fleet altogether. In the future, maintaining payload-shuttle compatibility for civilian and DOD payloads will be difficult unless this common-use principle is strongly supported at the highest levels in the Government, because each agency desires to maintain direct control over all aspects of their programs.

There have been suggestions that it might be appropriate to have DOD assume funding and management responsibility for the entire shuttle system after it becomes operational, for it appears that among the users DOD would have the largest number of missions. This role for DOD **would have several advantages:**

- as the major user, DOD could ensure compatible scheduling for its high-priority launches;
- under current budget constraints, operations costs and engineering refinements for the shuttle could more easily be funded by DOD; NASA could concentrate on science, applications and man-in-space programs; and
- security requirements for DOD payloads could more easily be accommodated ‘under DOD shuttle management.

The disadvantages of such approaches are considerable, however:

- NASA, as the development authority, has a detailed understanding of the shuttle and its complexities; this knowledge base is shared between the NASA centers and their contractors and cannot be easily shifted to DOD (or to any other organization);
- there are several non-U.S. payloads currently scheduled for launch by U.S. vehicles; these and future launches will be more difficult to accommodate under DOD management. There is likely to be some foreign resistance to cooperative programs dependent on DOD launches;
- the major technical support base for the shuttle—the NASA centers—would be in a different agency and would be less easily accessible to the operational manager (unless centers were transferred to DOD); this situation would create difficulties in implementing changes and improvements to the shuttle system; and
- the image of the U.S. space program would be altered; although still conducted for "peaceful purposes," it would be controlled by the military.

Man-in-Space

One of the features of the shuttle is that man is an integral part of the system, required for its successful operation and available to operate experiments, to deploy payloads, and to recover them in order to return them to Earth or to repair and refurbish them in orbit, as appropriate. For launch of DOD-operated systems, the astronaut crew will need to be aware of the system's operating characteristics and may be able to contribute to improved operation by using man's unique attributes. These may be DOD personnel or selected non-DOD astronauts. Clearly, foreign astronauts or experimenters could not be employed on such missions. Beyond this limitation, there is a great deal of commonality between civilian and DOD-operated missions, and significant advantage can be taken of this fact, with consequent net economies.

The next major step in advancing the capability of man-in-space is expected to be an extended lifetime manned space station in LEO. Experiments in such a station are likely to address civilian and DOD objectives, and the lessons learned will have significance for both civilian and national security purposes. Certain DOD missions, such as the possible launch of large space platforms with directed energy weapons, could require a significant role for men in orbit. A space station is likely to be of broad value for both civilian and national security purposes, and require continued DOD-NASA coordination for manned space flight. The current policy calls for such coordination, but the mechanisms are largely informal.

If a decision is made to proceed with space station development, it will likely be designed to satisfy broad national needs including those of the national security community. In order to satisfy this objective, the national security community will need to be brought into the space station program at an early phase, and should have a formal and significant presence **in the planning process** leading to program approval, when and if this occurs. The history of the shuttle demonstrates that such large-scale, long-term, and highly complex developments can be successfully pursued and be responsive to the needs of several agencies. The shuttle has also demonstrated that such programs are not easy to execute. Many of the problems with the shuttle concerning international perceptions, separating classified and unclassified systems and personnel, and devising a joint management structure, would recur with a space station. Given our experience with the shuttle, special attention should be given to providing adequate long-term funding from both the civilian and the military agencies.

Common-Use Systems (Unmanned)

The U.S. space effort has derived considerable benefit from its ability to use civilian and DOD technology almost interchangeably wherever such technology was most appropriate to mission needs (with the highly classified and sensitive DOD-operated systems a partial exception). Perhaps the earliest example was the use of DOD missile propulsion and guidance systems as space launchers. This joint use has continued, as the basic Thor, Atlas, and Titan missiles form the core of a modified and improved family of expendable space launch vehicles. Even the shuttle uses solid-fuel strap-on rocket technology with its roots in DOD missile experience and DOD space launches.

in spacecraft design, detailed characteristics of DOD-operated payloads are not generally revealed, but as described in earlier sections, there have been significant common uses in this area. Beyond detailed design features such as solar cell arrays, radioisotope power supplies, pointing and stabilization instruments, thermal coatings, temperature control devices (such as the heat pipe), fuel cells, small thrusters, and a host of other subsystems, there are several major systems that can meet both civilian and DOD needs.

One of the potential common-use areas is in navigation. The Department of Transportation is the lead agency for the civilian national navigation plan and is responsible for coordination of navigation system planning, with the Coast Guard and the Federal Aviation Administration as major participants. In space, however, DOD has taken the lead in the development of global navigation systems. In the earlier transit system and more recently in the new GPS system, DOD's needs are being addressed; civilian users are also being accommodated, though not with the same positioning accuracy as is available to DOD users. In general, civilian use has been considered in making GPS decisions, but non-DOD agencies have responded inadequately, leaving the entire burden of justification to the military rather than viewing GPS as a joint national system like the shuttle.

In telecommunications, the military makes use of civilian systems by leasing transponders from INTELSAT and from U.S. suppliers. The Navy, for example, uses maritime communications links provided by COMSAT'S MARISAT satellites. Present-generation communications satellites dedicated to DOD are not, however, normally shared with civilian users. As the technology continues to mature, and advance concepts such as the Large Communications Platform (LCP) become realistic possibilities, joint DOD-civilian LCPS may evolve. There are numerous issues surrounding the concept of LCPS that need to be resolved (discussed inch. 3), and the questions that result fro DOD involvement would add a further degree of complexity to ownership, management, funding, and use of such systems. There appear to be no insurmountable barriers to DOD involvement in an LCP, and there may be significant benefits from use of such a system. These factors suggest a general guideline that should be followed for DOD programs as well as for those **in the civilian sector: proposed DOD research, development, and demonstration programs in areas where there is significant civilian interest and technology base should be reviewed to determine if there is technology available from the civilian or commercial sector that can be applied to the DOD requirement.**

In other applications areas, such as meteorology and Earth (and ocean) observations, there is a degree of common use: DOD uses data collected from platforms primarily supplying civilian users. The executive branch has initiated periodic reviews of meteorological satellites (metsats) to ensure: 1) that maximum use is made of common systems, and 2) that if there are separate civilian and DOD platforms (as in the case of the medium-altitude metsats), there is a clear and persuasive justification for separate programs. For ocean observations, the concept of a NOSS was proposed as a common-use system to satisfy the needs of three agencies—NASA, NOAA, and DOD. Contributions to the program were to come from the three agencies, and the sensor systems and platform characteristics were to be determined by common agreement. Data were to flow into the two user agencies, NOAA and DOD; NASA was to be the principal space R&D agency. The planned multiagency sponsorship broke down, however, when DOD funding support did not materialize because of concern that the attempt to meet multiple needs would raise the cost beyond what the Navy was willing to pay.

The experience with NOSS indicates that **shared or common use of space** systems—although desirable from the standpoint of efficient use of national resources—does not occur, and cannot be sustained, without careful attention to management and funding channels and to approaches that reduce interagency stresses. It should be possible for the United States to carry out such multiagency programs, but the record to date has not been particularly promising. A similar situation exists in the land remote-sensing arena. There are multiple agency interests, both for civilian and national security purposes, in data from Landsat-type systems, but no single agency can justify the investment in a satellite platform. A cooperative agreement among agencies would appear to be one approach that could move the U.S. program from experimental to operational status. But long-term Cooperative funding of a common project such as this appears to be beyond our current capabilities.

Civilian Use of Data From DOD-Operated Systems

One of the delicate subjects in the relationships between civilian and DOD-operated space program activities is the use of remote-sensing data derived from classified systems for civilian purposes. There are presumably two security concerns related to the dissemination of data products from classified programs: sensitive technology and sensitive information content.

- The question of whether classified sensor or applications characteristics (e.g., sensor acuteness) are reflected in the data products of a classified system generally can be determined in advance for an entire class of products. Such products, in theory, could then become eligible or not, on the basis of technology, for direct utilization outside of classified controls and established need to know. Data might be modified so as to conceal the characteristics of the instruments used. In general, too, the sensitivity of technology declines steadily with the passage of time.
- The question of whether sensitive information content is contained in the products of a classified system, generally can be determined only on a case-by-case basis and even then may be very difficult to evaluate. For example, the possibilities of disclosing potentially embarrassing information about a foreign country are almost impossible to disprove, particularly in "worst-case" analyses, if the original sources of data were classified.

Information content, therefore, may have longer-lasting sensitivity than the technology involved.

The unyielding complexities and uncertainties of attempting to identify and weigh these two types of sensitivities have effectively limited civilian uses of the data products from systems that have primary national security-related missions. It is infeasible in an unclassified report to present a rounded evaluation of the mechanisms that are employed to declassify and disseminate information initially obtained from classified space systems. There are, however, some aspects that are appropriate for open discussion, and illuminate the types of issues that are involved:

- Executive orders that have defined the criteria for classification also provide for the orderly downgrading and ultimate declassification of data as their original sensitivity declines with age. Sensitive intelligence information is eligible for exemption from automatic downgrading at specified intervals, but not from the requirement for periodic review. As a result of these overall provisions, there are mechanisms and procedures within all national security related departments and agencies that regularly effect the release of data that were once classified. However, the delay often amounts to a decade or more.
- Information itself, even when derived from currently classified sources, is released occasionally to sharpen public understanding of issues or programs. DOD and the Department of State, for example, regularly report on the strategic-military capabilities and programs of the U.S.S.R. or other foreign countries. In such cases there is no reference or attribution to the specific source of the information. Such decisions inevitably turn on the judgment of the responsible officials, who weigh the potential benefits and risks. One problem is that many civilian agencies often do not have highly placed officials with the proper security clearances to deal directly with their opposite numbers in the military and intelligence agencies. This leaves key decisions entirely in the hands of national security authorities.

Any DOD/civilian program interaction in the use of classified data products, even through screening mechanisms controlled by national security interests, inevitably increases the exposure of the national security programs. At the same time, such joint activity imposes some national security controls or considerations on the civilian activities. While these relationships can be balanced within the context of Federal Government activities and operations, there are no mechanisms in place to handle such interaction with the private sector, State and local governments, or academia. **To make broad and routine civilian use of data products generated by classified systems it would be necessary to effect fundamental changes in policy at the national level.**

An important option, therefore, would be **to conduct an interagency review and/or a congressional inquiry of: 1) the degree to which national security systems can satisfy civilian user needs, and 2) the funds, personnel, and hardware required to satisfy appropriate needs. In the planning of next-generation DOD and intelligence systems, the possibility of accommodating well-defined civilian needs should be explicitly considered. It may also be appropriate to articulate a general policy in this area, in order to overcome the obvious reluctance of national security authorities to be burdened by considerations of civilian utility.** Such a policy directive might include the following points:

- DOD-operated systems will be designed to respond to national security needs and are consistent with the overall principles of "peaceful purposes," as stated in the NAS Act, and relevant treaty obligations such as the Outer Space Treaty;
- to the extent that such systems can satisfy civilian user needs, they will be planned and operated to do so, subject to the provision that acceptable performance of the primary missions be a priority;
- cost of incremental additional operations, hardware, personnel and supplies, to the extent these can be explicitly identified, will be borne by the civilian user or users; and
- there will bean interagency mechanism for coordinating the activities required to carry out the above tasks.

Institutional Change

Introduction

The world is a much different place in 1981 than it was in 1958, when the current policy and institutional framework for the national space program was developed. The United States and other leading countries have had almost 25 years to assess the ways in which space achievement might, as President Kennedy suggested in 1961, "hold the key to our future on Earth."

In carrying out the Apollo mission, NASA grew into a capable organization, one which became larger than anyone anticipated in 1958. On the basis of its over two decades of experience, NASA has also developed into a particular kind of institution in the eyes of the world, of the U.S. public, and of its own staff. Any consideration of changes in the overall structure of the U.S. space program cannot ignore the results of these past 23 years of activity. In particular, it must recognize that the political environment, especially the nature and scope of foreign competition and the degree of U.S. domestic support, has altered a great deal since 1958.

One major change is that the U.S. national security space program is larger and more vital to our defense posture than anyone except a few visionaries expected in 1958. As DOD and the intelligence community exploit existing space capabilities and explore the potential of future space systems, they have given an ever more important role to space technology in U.S. security planning. The national security space program has also evolved with particular institutional characteristics, and two decades have demonstrated that there are substantial differences in organizational style and methods between the civilian and military space programs.

As discussed previously, there have been repeated interactions between the separate space programs, and those interactions reflect a mixed record of cooperation and conflict. periodic assessments of this record and of the reasons for maintaining separate program structures have all concluded that the existing relationships are fundamentally sound, What the following discussion examines is whether this conclusion remains valid in the 1980's.

The Original Rationale Reconsidered

The reasons for establishing separate space program structures in 1958 were discussed previously. Briefly restated, they included: 1) that there were clear defense and intelligence applications of space technology, and that those applications, including the R&D supporting them, were best carried out under the management of national security agencies; 2) that there were also scientific, economic, and political justifications, not tied to national security applications, for space activities, and that these required a sizable nonmilitary space program; 3) that the national interest was best served by keeping these "other" space activities outside the national security framework, because:

- they were not relevant to DOD's mission and might even interfere with high-priority security-oriented space projects by, for example, competing for resources and technical talent or by making it harder to keep the security-related efforts classified; and
- the existence of a separate civilian space program meant that the United States could make use of that program as a tool of domestic and foreign policy by openly engaging in both cooperative and competitive international space efforts of a nonmilitary character, and could more easily transfer the results of the Government's space research efforts into the civilian economy.

This analysis will present the implications and alternatives that flow from differing assumptions about the civilian and military programs and their proper relationships. The issue is whether the advantages of maintaining the current separation outweigh the benefits of closer policy, institutional, and programmatic relationships among the various Government space programs. If it appears that there is no longer adequate justification for a large, institutionally distinct civilian space effort on the current scale of NASA, then the issue becomes how best to reduce or redeploy the existing capabilities (facilities and personnel) of the civilian space effort to meet current priorities and needs.

Options for Future Civilian-National Security Relationships

At this time the United States has a civilian space program which, despite past accomplishments and a high degree of technical and managerial expertise, is having difficulty gathering political and budgetary support for new programs. On the other hand, the national security uses of space technology are receiving high priority. From the national perspective, what would be the implications of a closer NASA-DOD relationship including even the possibility of merging the civilian, defense, and/or intelligence programs into a common structure?

There are three distinct kinds of relationships the two programs can have, depending on the status of the two sectors:

- Option 1: Separate Civilian and National Security Programs:
  - A. Separate projects with provisions for technology transfer (status quo).
  - B. Single project, with designated lead agency (space shuttle, metsats).
  - C. Ad hoc joint management/funding for specific projects.
- Option 2: independent Space R&D Agency for both civilian and national security projects (with operations conducted separately).
- Option 3: Absorption of elements of NASA by DOD and other Federal agencies.

The following will present the advantages and disadvantages of the three options.

Option 1:

Separate civilian and military programs.

The general rationale for this approach was presented in the previous section. In addition, there are specific pluses and minuses depending on how relations are handled:

A. Separate projects with provisions for technology transfer.—This is the current practice for most projects:

1. Benefits:
   - Allows defense and intelligence space programs to be managed in the context of their particular goals, without slighting civilian programs.
   - Preserves high degree of security for DOD/intelligence programs.
   - Maintains well-established management patterns for all sectors.
   - Stimulates beneficial competition between projects.
2. costs:
   - May lead to overemphasis within NASA on developing new technology rather than meeting national needs and satisfying potential users.
   - Accepts some duplication and inefficiencies.
   - Increases difficulty of planning and funding national programs of interest to civilian and military/intelligence sectors.
   - May lead to premature commitment to a major civilian post-shuttle development program to maintain vitality of independent civilian sector.

B. Single project with designated lead agency.—This has been the procedure adopted for the space shuttle (and attempted for NOSS), where both sectors are able to agree on the need for a common capability. One agency (in this case, NASA) is chosen as the lead agenc:y and designs and develops the technology according to its own management procedures, in consultation with other users. In the case of the shuttle, the current plan is that operations will also be managed by one agency:

1. Benefits:
   - Avoids duplication of effort and associated costs.
   - Increases political and financial support for long-term projects.
   - Facilitates coordination between developer and user.
2. costs:
   - Leads public and international community to confuse civilian and military programs.
   - In the case of the shuttle, has absorbed a disproportionate amount of

NASA budget and personnel, without direct support from DOD; lead agency tends to be left "holding the bag."

C. Joint management/funding for selected projects.–This has not been the practice, but might be useful to avoid some of the problems associated with separate programs and lead agency responsibilities:

1. Benefits:
   - As for the previous case; in addition, joint management and funding would ensure careful attention by both parties and ease the strains on the lead agency.
2. costs:
   - As above; however, joint management might complicate decision-making.

Given the underlying separation of the civilian and national security programs, any of the above three approaches can be used for specific projects. This gives management considerable leeway in establishing patterns for cooperation and funding; in the case of joint civilian-military projects, congressional oversight would have to involve several subcommittees.

Option 2:

Independent space R&D agency for all Federal space projects, civilian and military.

In this case, an essentially new agency would be created to manage all U.S. **space-related** R&D. Based primarily on existing NASA and Air Force capabilities, the new agency would be oriented toward serving a variety of national needs, including those of DOD and the civilian agencies (Departments of the Interior and Agriculture, etc.). The operation and maintenance of systems, once developed, would be the responsibility of the mission agencies.

1. Benefits:
   - Links NASA's technical capabilities in areas such as manned space flight and space propulsion to high-priority national security objectives.
   - Provides political support and policy rationale required to preserve the major part of NASA's facilities and personnel.
   - Allows for budgetary and programmatic coordination of entire U.S. space R&D effort, civilian and military, including what are now distinct DOD programs; better balance between technology push and user pull in what are now NASA programs.
   - Permits total Federal space budget to be adjusted to policy priorities and allows the new agency to be reimbursed from other Government agencies and private sector for its R&D work in direct support of their requirements.
   - Routine links to users would facilitate transition from R&D to operations for programs now in NASA.
   - Facilitates joint programs in areas such as space transportation of interest to entire space community.
2. costs:
   - Inverse of most benefits of option 1; puts the space agency in a less public support role and makes it difficult to use for political and foreign policy purposes.
   - Likely, in current context, to result in unbalanced R&D program with national security requirements predominant (this might also be considered a benefit).
   - Disrupts established DOD-contractor relationships.
   - Does not answer question of what to do with space science programs such as planetary exploration, because agency emphasis would be on user-oriented applications; likely to lead to reemphasis of space science.
   - Potential loss of NASA's role as innovator and developer of new technologies relevant to the civilian economy.
   - Some highly classified national security programs will still remain off-limits.
3. Requirements:
   - Establishing extensive pattern of

mutual trust and cooperation between new agency and various users of its R&D services.

- Requires some means for resolving conflicts between different users over how to employ the new agency's technical capabilities and over priority to be given to different program activities.
- Change in congressional oversight of civilian space activities, with more emphasis on mission-agency oriented committees (Armed Services, Agriculture, Natural Resources, etc.).

Option 3:

Absorption of NASA by DOD and other Federal agencies.

In this case, NASA would be dissolved with key elements, such as the centers, being taken over by DOD, other Federal agencies, and private firms or universities:

1. Benefits:
    - May reduce costs.
    - Links technical and institutional capabilities relevant to national security objectives directly to users within DOD and intelligence agencies.
    - Minimizes problems of transition from R&D to operations.
    - Provides opportunity to trim or eliminate nonessential parts of NASA institutional base.
    - May facilitate transfer of space systems to the private sector.
2. costs:
    - Loses the benefits posited for option 1.
    - Gives up an established and successful institution for uncertain efficiencies and budget savings.
    - Not clear that NASA centers could easily be absorbed within DOD and other mission agencies.
    - No single locus for space R&D in support of civilian mission agencies and U.S. private sector.
    - Public and congressional reaction likely to be mixed, but predominantly negative; same for overseas reaction.
    - Makes ambitious civilian programs such as Apollo or permanent manned stations much more difficult to consider.

Chapter 7

INTERNATIONAL EFFORTS IN SPACE

Contents

LIST OF TABLES

LIST OF FIGURES

Chapter 7

INTERNATIONAL EFFORTS IN SPACE

INTRODUCTION

The shape, direction, and very existence of the U.S. civilian space program owe much to international competition. The basic events are well known: the launch of Sputnik in 1957 and the sudden public discovery of the "space age;" the continuing series of Soviet space "firsts" in unmanned and then manned satellites; and the sometimes desperate attempts by the United States to catch up, culminating in President Kennedy's 1961 commitment to a manned lunar landing by 1970, ahead of the Russians. (For a more detailed description of the early phases of Soviet-American rivalry in space, see app. G.)

During these years of competition the United States and the Soviet Union had a virtual monopoly on space systems and technologies: boosters; tracking systems; communications, remote sensing, and weather satellites; and manned spacecraft. Other countries, lacking the military and political motivation, did not at first choose to expend the resources needed to develop independent space capabilities.

We will not attempt hereto describe the course of these developments during the 1960's; the main elements of the current Soviet space program will be presented later (see pp. 204-209). Suffice it to say that the U.S. program had, by the end of the decade, succeeded in demonstrating its superiority in virtually every area—without, however, forcing the Soviets to abandon their own efforts or to concede permanent U.S. preeminence.

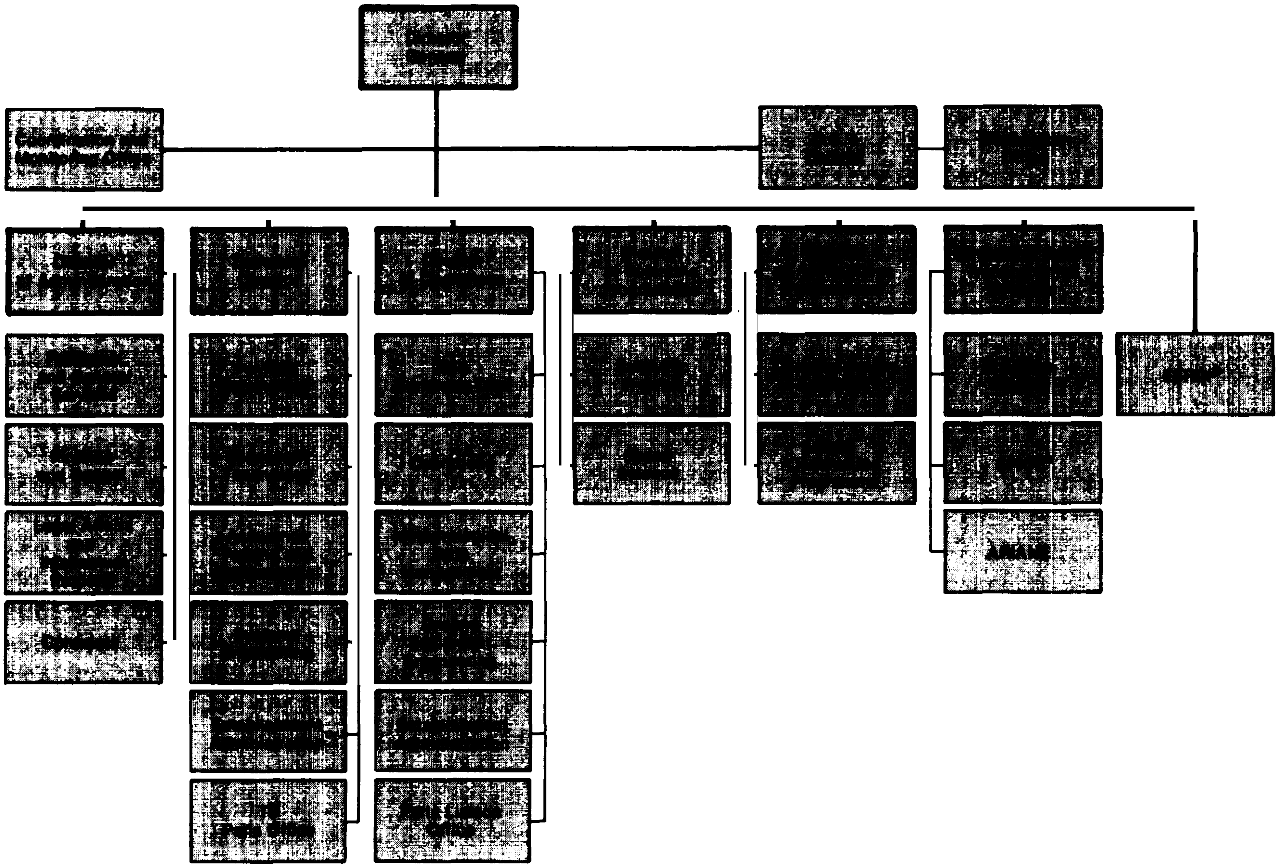
The important point is that, beginning in the 1960's but accelerating rapidly in the 1970's, other countries began to enter the field. Political motivations, as will be seen, played and continue to play a crucial role; to a large extent these were identified with maintaining economic competitiveness vis-a-vis commercial rivals, particularly the United States. As the U.S. post-Apollo space activities, both public and private, have come to concentrate more on potential economic payoffs rather than on large prestige projects, and the Soviet program has turned toward the long-term goal of permanent manned orbital platforms, the commercial competition in space applications technologies and systems from Europe and Japan has become increasingly important. The significance of competition between nations has also altered, due to the expanded global use of space technology rising largely out of the successes of the U.S. space program. International organizations for global communications, such as INTELSAT and INMARSAT, have continued to grow and now include most of the world's users of telecommunications. Through the National Aeronautics and Space Administration (NASA) and the U.S. Agency for International Development, many developing countries have gained first-hand experience in the ways satellite communications and remote-sensing systems can supply services crucial for economic growth. As one result, the laws and regulations governing the use of outer space have been widely discussed by international bodies such as the International Telecommunication Union and the U.N.'S Committee on the Peaceful Uses of Outer Space. Space technology has become an important political resource whose effective use by the United States will be affected by the development of international competition. In what follows we will outline, for each major foreign program, its organization and goals, its main efforts in the four applications areas (communications, remote sensing, materials processing, and transportation), and the prospects for cooperation and/or competition with the United States.

EUROPEAN SPACE AGENCY AND JOINT EUROPEAN EFFORTS

Since the early 1960's Europe has attempted to mount a coordinated space program to compete with the United States and Soviet programs in key areas and to ensure European participation in the economic, scientific, and political benefits of space activities. The latest and most successful organization to attempt this task is the European Space Agency (ESA), made up **of 11 full members—Belgiu m, Denmark, France, Germany, Ireland, Italy, the Netherlands, Spain, Sweden, Switzerland, and the united Kingdom–and two associate members—Austria and** Norway. ESA **is involved in space science, applications, and launch vehicle development, as well as the formulation of policy** for European cooperative ventures (see fig. 1 1).

At the **beginning of the space age, individual European states recognized that they could not mount space programs on the scale of those in the United States or** U.S.S.R, unless there was extensive cooperation among interested parties. Even so, there was no attempt to match the manned capabilities being competitively developed by the superpowers. European interest has been focused on basic science, on applications satellites for regional use, and on supporting an industrial/technical infrastructure that could contribute to high-technology enterprises. Despite these shared interests, however, there have been continuing difficulties caused by: 1) differences between members about what programs to support and general policies to follow, 2) problems

Figure II.—Organizational Structure of the European Space Agency



[a]SPICE - Spacelab Payload Integration and Coordination in Europe
[b]ESRIN - European Space Research Institute (includes Earthnet), Frascati, Italy

SOURCE: *Europe's Place in Space* p. 6.

in allocating contracts between industries in various countries, 3) disagreement about the appropriate degree of cooperation with, and dependence on, the United States, and 4) competition between ESA and national programs.

Policy and Budget

ESA was founded in May 1975 following several years of negotiations and compromises among the major participants. ESA inherited the programs and facilities of its predecessor organizations, the European Space Research Organization (ESRO), the European Launcher Development Organization (ELDO), and the European Space Conference (ESC). (For a description of Europe's pre-ESA activities, see app. G.) An important point is that, unlike NASA, ESA is specifically allowed to operate applications systems, once developed, with the costs being borne by the users of the system.1 A second difference, one which partially offsets the first, is that ESA is responsible for carrying out an "industrial policy" designed to "improve the worldwide competitiveness of European industry," while ensuring that member states participate equitably and, in particular, that the return to any member state—i.e., the value of the contracts let by ESA—is approximately proportionate to the members' contributions (the principle of "juste retour" or fair return). The ESA convention explicitly states that it shall "exploit the advantages of free competitive bidding in all cases, except when this would be incompatible with other defined objectives of industrial policy. "z Hence considerations of cost or efficiency may have to take a back seat to the principle of fair return, with predictable results for timeliness and cost effectiveness. This is one of the inevitable shortcomings of a mu ltinational agency, and a prime reason why operational systems have generally been handled outside of ESA.

The ESA members contribute to the organization in two ways: mandatory activities, which include the scientific programs and basic organizational expenditures; and optional activities, which are specific programs for satellite design and operations, launch facilities, and space transportation.[3] The major programs, such as Ariane and Spacelab, are optional, which means that members can request to be specifically excluded. Mandatory contributions are based on each state's national income; however, no one state can contribute more than 25 percent of the total budget. For optional projects, interested participants pay a variable percentage which is negotiated between the participants. The degree of national support for various programs in 1981 is given in table 17.

ESA'S budget for its first full year of operation (1976) was approximately $600 million, of which one-third went for mandatory and two-thirds for optional programs. This compares with NASA's fiscal 1976 appropriation (for space) of $3.22 billion. In 1980, ESA'S budget had risen to $846 million, while NASA's was $4.68 billion. In both years, the ESA budget was between one-fifth and one-sixth NASA'S. (These figures do not constitute a complete comparison of United States and European civilian space expenditures, since they fail to include non-NASA programs in the United States, both Government and private sector, as well as the space budgets of individual European countries). Since ESA'S two most expensive projects, Ariane and Spacelab, are largely complete and are not likely to be soon replaced by comparable programs, ESA'S budget is not expected to increase over the coming years.[4]

Current and Projected Applications Programs[5]

Communications

European communications needs and programs have been defined largely by the national PTTs (postal, telephone, and telegraph agencies) acting through CEPT (Conference Europeene de Postes et Telecommunications and the European

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I "Convention for the Establishment of a European Space Agency," done at Paris May 30, 1975, art. V.

"'Convention," art. VI], par. 1 sec. d.

3"Convention," art. V.

[4] As a multinational organization, ESA has had to develop an accounting system to provide for changes in exchange rates between member states. ESA accounts are kept in ESA Accounting Units (AU) rather than any single national currency. The value of the AU vis-a-vis other currencies is reevaluated annually; in 1981, one AU = $1.4.

'Unless otherwise indicated, figures and information in this section are taken from *Europe's P/ace in Space*, ESA, Paris, January 1981.

Table 17.–Contributions of Member States to the Principal ESA Programs in 1981

	General budget	Science	Meteosat expioita-tion	Sirio-2	OTS	ECS	ECS phase 3 bis	Marecs A	Marecs B	Spacelab	Ariane develop-ment
Member states:											
Belgium	4.71	4.49	4.06	3.30	5.17	3.27	3.19	0.95	0.14	5.07	1.92
Denmark.	2.63	2.51	2.41	—	2.90	0.33	0.74	—	—	1.81	0.40
France	22.45	21.40	23.70	7.50	24.69	25.93	26.52	11.92	5.74	12.07	79.34
Germany.	26.82	25.57	25.66	9.00	25.00	30.68	30.42	19.08	13.29	64.78	5.31
Ireland	0.54	0.54	—	—	—	—	—	—	—	—	—
Italy.	5.51	12.46	15.07	72.39	14.38	14.78	13.85	2.20	1,28	1.00	5.31
Netherlands.	6.29	6.00	—		2.50	0.94	1.77	4.63	1.49	2.53	0.34
Spain	5.29	5.04	—	0:50	—	0.17	0.53	0.95	0.34	3.38	4.18
Sweden. , ., ... , . .	4.16	4.25		1.50	4.91	1,62	3.97	2.96	6.61	—	0.63
Switzerland	4.19	3.99	3·48	3.50	4.59	2.13	0.55	—	—	1.00	0.08
United Kingdom . .	14.42	13.75	20.60	1.83	15.86	20.15	18.46	55.81	69.89	7.60	2.49
Other participants:											
Austria	0.68	—	—	0.48	—	—	—	—	—	0.76	·
Canada.	2.23	—	—	—	—	—	—	—	—	—	—
Norway.	0.08	—	—	—	—	—	—	1.50	1.22	—	—
Other income.	—	—	5.02	—	—	—	—	—	—	—	—

SOURCE: From *Europe's Place in Space*, p, 9.

Broadcasting Union (EBU). More recently, forecasting and coordination have been done within the Interim Eutelsat Organization, set up within CEPT in 1977 to establish a European satellite communications system.

OTS ***(Orbital Test*** Satellite).–The OTS project was approved by ESRO in 1971 and launched into geosynchronous orbit in 1978 (aboard a U.S. Delta 3914) after development by British Aerospace Dynamics Group. With a capacity of 3,000 telephone circuits, it has been used for various experimental purposes including high-speed scientific data transmission and television broadcasting. Current projections are that it may be able to provide useful services for up to 5 more years. Program cost has been $365.4 million.

ECS (European Communications Satellites).– The OTS was designed to prove the usefulness of an operational European telecommunications system. In 1978, ESA approved a five-satellite system, based on the OTS design, to provide regional communications needs for 10 years. interim Eutelsat will pay user fees for international trunk telephone services and for television transmission between members of the European Broadcasting Union. High-speed data transmission and communication with off-shore oil and gas platforms may also be provided. British Aerospace Dynamics Group is the prime contractor for the estimated $632.8 million program (not including ground terminals); the first satellite is scheduled for an Ariane launch in 1982.

Marecs.–Marecs is a direct descendant of Great Britain's Marots program for ocean communications, but its design is based, like ECS, on the experimental OTS. Two satellites will be placed in geostationary orbit over the Atlantic (the Atlantic satellite may eventually be relocated over the Indian Ocean) and Pacific to provide ship-to-ship communications. The international maritime satellite organization, inmarsat, is leasing the satellites for its mission. The British Aerospace Dynamics Group is prime contractor, and Britain has put up most of the development funding, some 55 percent of Marecs A and almost 70 percent of Marecs B. (In the OTS and ECS programs, by contrast, Great Britain contributed a more usual 15 to 20 percent.) Marecs A was launched on the fourth Ariane test flight December 20, 1981, and Marecs B is scheduled for the first operational flight in September 1982. Program cost is $359.8 million.

L-Sat (large-satellite). –The L-Sat is a descendant of an earlier program, H-Sat, which was abandoned by France and Germany in favor of going ahead with more rapid deployment of their own joint (non-ESA) operational communications and television direct broadcast system (see description, p. **188).** As presently envisioned, L-Sat would be a very large, advanced experimental communications satellite to test the feasibility of direct TV **broadcasting and specialized/business communications using small roof-top size terminals. In addition, it would include equipment** for experiments with the as-yet unexploited 30/20 GHz band. The British have been most enthusiastic about L-Sat development, which is seen as competitive with U.S. technology for future INTELSAT satellites, and British Aerospace has been awarded the prime contract. Still in the design definition stage, its estimated launch (either on the space shuttle or an advanced Ariane), is set for 1986. The estimated development cost is $520 million (1 980 price levels).[6]

One of the striking facts in looking at ESA'S communications program is the leading role played by Great Britain and British industry. Since there are national and bilateral European projects being conducted outside ESA, Britain is not the only European country fostering satellite telecommunications expertise, but it has one of the broadest and most forward-looking programs (see pp. **40-41** for further discussion).

Remote Sensing

ESA has been active in both meteorological and remote-sensing development, though with primary emphasis on the former,

Meteosat 7 ***and*** 2.—The Meteosat program was approved by ESRO in 1972; Meteosat 1 was launched (by Thor-Delta) in 1977, and placed in a geostationary orbit allowing it to survey Europe, Africa, and the Mediterranean. It provides raw imagery to central European ground-processing stations for short-term weather forecasting, as well as relaying the processed data to users and transmitting imagery from U.S. weather satellites stationed over the Western Hemisphere. Meteosat 1 has also contributed to global programs set up by the World Meteorological Organization. in 1979, Meteosat 1 suffered a partial failure of its power system; Meteosat 2 was launched in June 1981 on the third Ariane test flight. The prime contractor for the $301 million program was Aerospatiale of France.

Sirio 2.—Sirio 1 was an experimental Italian communications satellite; the spare, Sirio 2, will be launched by ESA in 1982 to provide meteorological data transmission to African ground centers, as well as to conduct scientific experiments. Cost for the Italian-built satellite will be $40.6 million.

Earthnet. -A mandatory ESA program, Earth net consists of four receiving stations and two processing centers which receive remote-sensing and meteorological data from U.S. satellites: Landsat, Nimbus-7, the Heat Capacity Mapping Mission, and (formerly) Seasat. The data are available to all ESA members as well as to outside requesters.

Spacelab Remote-Sensing Programs. –The first Spacelab flight, scheduled for 1983, will carry two European remote-sensing experiments. One will use a very high resolution camera for 1:100,000-scale mapping. The second involves the development of a microwave remote sensor to collect data through cloud cover.

ERS 1 (European Remote-Sensing Satellite).– The Earthnet and Spacelab projects, along with other activities, are designed to prepare for an advanced remote-sensing satellite, ERS 1. ERS 1 will be used to monitor icepacks and to sense coastal and ocean regions; its instruments include a synthetic aperture radar, a radar altimeter, and wind and wave scatterometers. Tentative launch date is mid-1987. (It should be noted that a major civilian operational/commercial remote sensing system, SPOT, is being undertaken by France, Sweden, and Belgium as a national project; the proposed ERS will use the SPOT bus but contain different instruments. For a description of SPOT, see pp. 25-29.) ERS-1 is considered to be one element i n a continuing program of Earth observation satellites. Studies are underway for further satellites, including one for land remote sensing.

Materials Processing

ESA does not yet consider materials processing to be an applications area per se, but rather an area in which to do basic research that may someday lead to useful products or processes.

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[6] ESA **News** Release, "New European Telecommunication Satellite, Program is Approved," Dec. 22, 1981. ESA **News Release, "ESA** Microgravity **Programme Gets Underway, "** Jan. **18, 1982.**

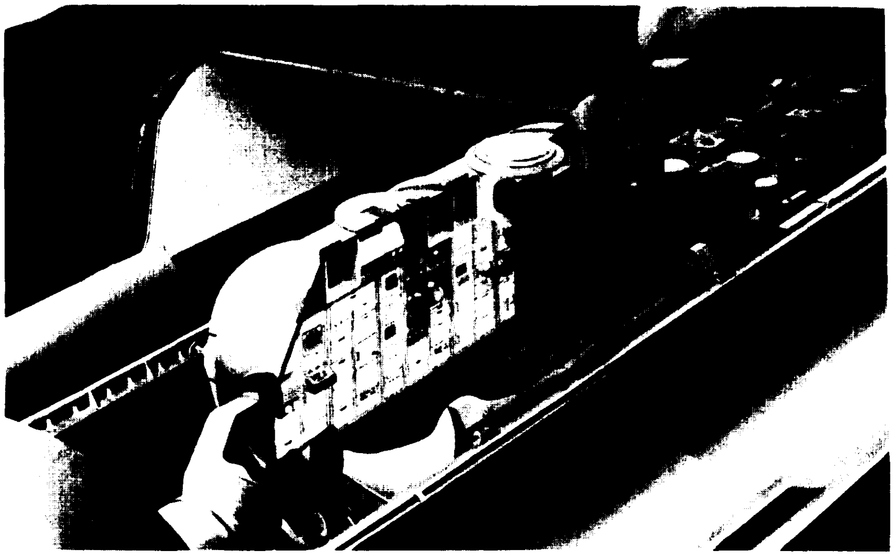

Illustration: Courtesy of European Space Agency

Spacelab (artist's conception)

The term "materials science" is used instead of materials processing; experiments in both biology and materials science will be carried out as part of an approved 4-year "microgravity programme" budgeted at $52.4 million.[7]

ESA'S main contribution to materials science will be through Spacelab, although sounding rockets are also being used. Spacelab will be the major facility for space-based experimentation in the physical and biological sciences during the next decade. Spacelab consists of a pressurized module capable of being carried in the payload bay of the space shuttle and allowing experimenters to work at a variety of projects in a shirt-sleeve environment. There are also pallets that allow equipment to be exposed directly to vacuum and radiation (see artist's rendition). Equipment for conducting processing experiments will include furnaces and remote manipulators.

Spacelab is ESA'S largest cooperative project with NASA. ESA is responsible for designing and delivering, free of charge, an engineering model and a first flight unit (delivered in December 1981), which NASA is scheduled to launch in mid-l983. The first flight program will involve a joint European-American crew conducting a variety of test projects. In 1980, NASA contracted to purchase a second spacelab, including a pressurized module and five instrumentation pallets, for $183.9 million from the prime contractor, the German firm ERNO.[8]

Spacelab is Europe's first attempt at constructing a manned system; partly for this reason, and also because of internal management problems compounded by continuing changes in the requirements for integration with the shuttle orbiter, the project has cost considerably more than initially estimated, and has also been subject to delay. The 1973 agreement between NASA and ESA called for delivery of the first unit by 1979; however, since the shuttle program has also been behind schedule, these delays have had little effect. The increase in costs, however, has caused problems among the ESA supporters. According to the ESA agreement, if costs rose above 120 percent of original estimates, the supporters could withdraw or renegotiate the terms. In 1979, estimated costs to completion (approximately $860 million; dollar amounts are inexact because of built-in inflation escalators and exchange-rate fluctuations)[9] were 140 percent of the original

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[7] ESA News Release, "ESA Microgravity Programme Gets Underway," Jan. 18, 1982.

[8] "Europe Competes With U.S. Programs, " *A W&ST,* Mar. 3, 1980, p. 89.

[9] "Sweeping Changes Spur Spacelab Pace, " *AW&ST,* Feb. 11, 1980).

estimates. Italy in particular felt it could not continue to fund Spacelab at its original level of 18 percent and threatened to block the project (largely because its share of Spacelab's industrial participation had fallen to 11 to 12 percent) unless its contribution was reduced. As a result, Italy's contribution dropped from 18 percent in 1979 to 1 percent in 1981, with the shortfall being taken up by other contributors in proportion to their level of participation.

There have also been various tensions between NASA and ESA over secondary issues. One problem has been the flight schedule for Spacelab missions, especially since the number of shuttle flights for the first several years has recently been cut back. ESA is also concerned that changing specifications for shuttle payloads will lead to expensive redesign of Spacelab components. " Some European scientists think that NASA requirements for documentation and prior consultation on Spacelab experiments are overly stringent and reflect a desire to restrict European participation .12 NASA counters that preparations for manned missions are of necessity more rigorous than for other types of flights. Some Americans think that, despite the money saved by cooperative development, an American Spacelab program would have been faster and would have produced a design better suited to U.S. needs and to the shuttle's capabilities, and that the (politically motivated) inclusion of the Europeans has resulted in a less-than-optimal technology.

It is difficult to evaluate these charges and countercharges objectively; in large part, they stem from the inevitable problems of conducting any major cooperative program in advanced technology, especially one with significant potential economic effects. Since, for budgetary reasons, the alternative to a European Spacelab was not a U.S. Spacelab, but no Spacelab at all, many U.S. criticisms are strictly hypothetical. The question of who will exploit Spacelab's capabilities most effectively-the United States, the Europeans, or perhaps the Japanese—remains open.

Launch Vehicles

The Ariane I launcher, ESA'S most expensive single program, has recently completed a four-flight test program; the first operational flight will take place in September 1982.

Ariane I is a three-stage expendable vehicle, including an advanced liquid oxygen/liquid hydrogen third stage. For a comparison with U.S. launch vehicles, see table 18.

The current design of Ariane is only the first in a series of as many as five models; successive designs are planned to improve payload capacity and performance through the 1980's. The ESA member states have already approved a program to develop Ariane 2, 3, and 4. Ariane 2 will be able to place 4,400 lb in a transfer orbit, and Ariane 3,5,280 lb.13 Ariane 4, under study by ESA and CNES, will more than double the performance of Ariane 1; its further development was approved in January 1982, and first launch is scheduled for 1985. An even more ambitious improvement, a fifth Ariane version having a liquid oxygen/liquid hydrogen second stage and able to launch 12,100 lb into transfer orbit, is also under consideration for potential development by the end of the decade.

Table 18.—Capacity of Ariane and U.S. (Commercial) Launch Vehicles (in lb)

	LEO	Transfer orbit
Ariane 1	**10,500**	**3,700a**
Space shuttle	65,000	—
Space shuttle with Delta upper stage	—	2,750
Space shuttle with internal upper stage (under development)	—	5,000
Thor-Delta	6,490	2,420
Atlas-Centaur	11,200	4,510

[a] These figures assume the Ariane is launched from the Kourou launch site near the Equater, while U.S. launches are from Kennedy Space Center in Florida. The equatorial site gives any geostationary payload an approximately 15 percent performance improvement over KSC

SOURCE: Office of Technology Assessment

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[10] Chris Bulloch, "Spacelab Status: Some Action at Last," *Interavia*, November 1981, p. 1,168.

[11] Eric Quistgaard, Director General of ESA, statement before Senate Commerce Committee, Mar. 25, 1981, p. 7.

[12] "U.S.-Europe Collaboration Variable," A W&ST, Sept. 1, 1980, p. 275.

[13] Jeffrey Lenorovitz, "Arianespace Completing Payload Plans," *AW&ST*, July 6, 1981, pp. 19-20.

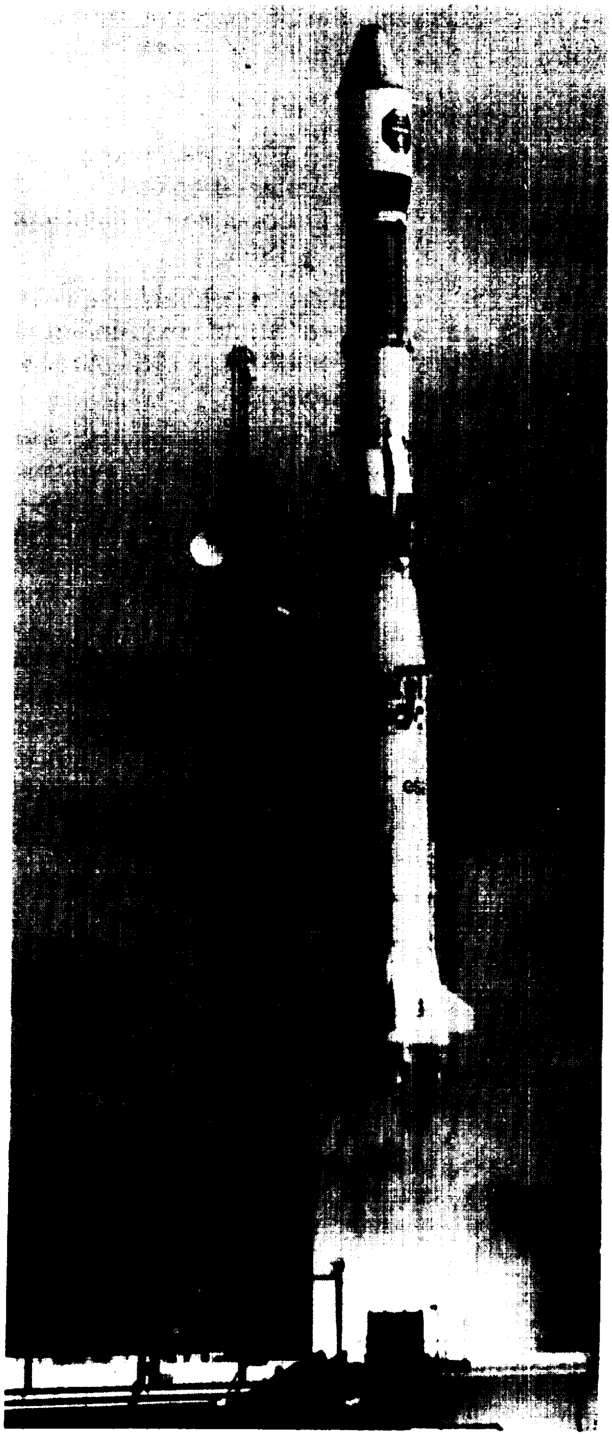

Photo credit European Space Agency

First launch of *Ariane I*

Utilizing a dual launch system (SYLDA), each Ariane is capable of carrying two separate payloads on each flight. Launches will be made from the French-owned, ESA-funded Kourou spaceport in French Guiana, South America. Located close to the Equator, Kourou is well placed for launching stationary satellites (which orbit over the Equator). With only one pad, it is currently capable of launching five to six flights per year, but construction of a second pad has been approved for operation in 1984 or 1985, allowing for 10 annual launches and providing redundancy.

When the Ariane was first proposed, there was considerable skepticism as to whether it could be competitive with the space shuttle and the various U.S. expendable vehicles. There were strong political reasons why several European countries, especially France, desired an independent launch capability (see app. G); in addition, it appears that, as a result of several considerations, the Ariane will be able to compete with the shuttle for many kinds of payloads through the 1980's. First of all, the shuttle itself is 2 years behind schedule, and has not yet been flown sufficiently to convince users of its reliability. Second, U.S. production of expendable was slowed down and in some cases virtually halted, in expectation that the shuttle would replace all of them during the early 1980's. As a result, the cost of the Thor-Deltas and Atlas-Centaurs has risen sharply over the last several years. Third, the commercial demand by a number of likely users, especially for communications satellites, is projected to be much larger in the coming decade than was previously thought. Even with the shuttle operating at its initially projected pace, there would be demand for additional launch services.ld However, because of recent and projected budget cutbacks there will be fewer shuttle flights than previously scheduled, another circumstance forcing users to turn to alternate launch vehicles. Fourth, Arianespace is offering customers highly attractive terms, including below-market financing through European banks, and an extended period in whic:h to make repayment. For these reasons, the Ariane is likely to

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[14] Jerry Grey, **"Case for a 5th Shuttle and More Expendable Launch Vehicles,"** *Astronautics and Aeronautics,* **March 1981.**

have a full manifest for the foreseeable future, despite the superior capabilities of the shuttle. Frederic D' Al lest, chairman of Arianespace, projects continued use of Ariane for at least 20 years despite competition from reusable spacecraft.[15]

The Ariane is now scheduled for a series of ESA and INTELSAT launchings (under ESA auspices) in 1982. As of january 1982, there were approximately $350 million worth of firm orders for Arianespace, which will take over Ariane operations in 1983.[16] There were also a large number of reservations, which may be turned into firm orders in the future. These include non-European customers such as Colombia, Australia, and the Arabian Satellite Corporation.[17] Recently, Arianespace received its first firm order from an American company, General Telephone & Electronics, to launch two domestic communications satellites **in 1984.**[18] Other orders have followed from Western Union and Southern Pacific Communications. Ariane is being marketed in the United States through an arrangement with Grumman Aerospace Inc. Arianespace policy is to sell its services to "any customer whose payload is designed for peaceful use;" this includes payloads from the French military, NATO, and a British Defence Communications Satellite.[19] Control over the political aspects of launch policy is retained, according to ESA'S agreement with Arianespace, by the ESA Council.

The development and subsequent operation of Ariane have been marked by a number of peculiarities. We have seen the dominant role that France played in proposing and developing the project. The prime contractor has been not a private firm or industrial consortium, as for other ESA programs, but CNES (Centre National d'Etudes Spatiales or National Center for Space Research), the French Government equivalent of NASA. CNES in turn has let contracts primarily to French firms, in particular Aerospatiale, the prime contractor, and SEP (Societe Europeenne de Propulsion), which is building the propulsion system. Overall, France has funded over 60 percent of the project, rising to 79 percent in 1981.

Perhaps the most interesting aspect of the Ariane program is the arrangement for commercial operation. Instead of leaving it to ESA or CNES, a quasi-private corporation called Arianespace has been established to produce, finance, market, and launch Ariane vehicles. ESA and CNES remain responsible for further development of Ariane 2-5, and for operation of the Guiana spaceport.

Arianespace is incorporated in France and owned by firms from the states that funded Ariane's development, by CNES, and by European banks. French investors (including CNES itself, which is the largest single shareholder with 34 percent), will own 60 percent; German ones 20 percent; and the remainder is split up into smaller portions. Its initial capitalization was approximately $20 million. The first chairman of Arianespace, Frederic D'Allest, is the former CNES project director for Ariane, and the production and launching teams will be transferred directly from CNES in 1982.[20] Clearly, the new firm will be dominated by the French, and it is not surprising that France was the prime mover behind Arianespace's emergence. The idea of a private firm was first suggested in 1979, with the original proposal by CNES calling for 70 percent French ownership. The basic rationale was that only a commercially oriented operation could manage Ariane so as to compete effectively with the shuttle; trying to operate in a framework requiring the unanimous consent of 11 sovereign nations would be far too inefficient.[21] In subsequent negotiations with ESA and the potential partners, the French percentage was reduced to approximately 60 percent. The most difficult part was getting the agreement of other ESA members to turn over the technology and facilities, including future developments, to Arianespace; Germany was particularly opposed. In 1980, France withheld support for Spacelab funding for 2 months until Germany signed a political dec-

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[15] Jeffrey Lenorovitz, "Arianespace **Completing Payload Plans,"** *AW&ST*, July **6, 1981, p. 19.**

[16] "Why **NASA's Shuttle May be Left** in the Dust," **Business** *Week*, **Jan.** 18, 1982, p. 38.

[17] "Arianespace Press Kit," at 34th International Airshow, Paris, June 1981, pp. **10-13.**

[18] **"Europeans Win Orders to Launch 2 GTE Satellites,"** *Wall Street Journal*, **Nov. 25, 1981.**

[19] Arianespace **Press Kit, p.** 13.

[20] Arianespace **Press** Kit.

[21] "Europeans Organize Commercial Ariane Satellite Launch Company," *AW&ST*, **July 9 1979,** p. **18.**

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laration agreeing to the transfer to Arianespace.[22] Arianespace is currently scheduled to assume responsibility in 1983 following a series of seven ESA flights in 1982 and early 1983.

Future Plans

with the imminent completion of ESA'S two **largest** applications programs, Spacelab and **Ariane,** the level of ESA activities in the 1980's **is likely** to diminish, For the immediate future the **valuable industrial and technical teams organized** for these projects will remain occupied building the second Spacelab and designing Ariane 2-5. No comparable applications projects have yet been approved to take their place (though there has been consideration of a plan to develop Spacelab into a free-flying platform as part of a cooperative program with the United States). A reduction in ESA activity may reflect the preference of several member nations for national or bilateral programs, especially for commercial applications systems, where the cumbersome ESA apparatus can impede timely decisions. **It also** reflects a general worsening of the major European economies over the past several years, especially those of West Germany and Great Britain. Under its recently elected Director General, Eric Quistgaard, ESA has been preparing a 10-year plan for the future which is likely to emphasize basic science within an overall reduced budget. The proposed plan estimates a reduction to an annual budget of $532 million to $598 million, compared with a 1980 level of $845.8 million .23 in establishing future programs, it will be necessary for the major partners to compromise as they did in the past. The British interest in L-Sat development remains high, while the Germans are **more interested** in exploiting Spacelab by conducting scientific and materials processing missions, and expanding Spacelab's capabilities. France would like to see aggressive development of the Ariane, including a possible automated processing station (Solaris) or a manned reusable vehicle. [24]If a successful compromise is not reached, many of these programs may become exclusively national efforts.

According to an address given by Dr. Massimo Trella, Technical Director of ESA, at the Paris Air Show in June of 1981, overall European space activities will continue to grow in the 1980's at least as rapidly as in the 1970's, but the division of responsibility between ESA and national efforts can be expected to change. ESA and the various national programs will cooperate in defining and coordinating a European program, while ESA itself "will build up, more than before, its identity as an R&D organization devoted mainly to large projects. More clearly we **believe that commercially exploitable systems should be more the responsibility of other initiators** in Europe. " Dr. Trella specifically mentioned development of an advanced remote-sensing system .25 However, on the same occasion Michel Bignier, ESA'S Director of Space Transportation Systems, outlined a future program which emphasized materials processing, development of Ariane 3 and 4, and building and maintaining large space stations.[2b] Clearly ESA'S future mix of programs and overall emphasis remain to be determined.

Cooperation/Competition With the United States

Cooperation:

The bulk of European cooperative efforts with NASA have been scientific. With one major exception (to be discussed below) these have worked out well. A large number of cooperative missions, in which NASA provided free launch services in exchange for scientific experiments and data, have been conducted with ESRO and ESA.[27] In general, scientific cooperation is arranged directly between ESA and NASA; only Spacelab has required a formal intergovernmental agreement. (Lower level agreements, called

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[22] "New Commercial Organization to Take Ariane Responsibility," *AW&ST,* Apr. 7, 1980, p. 45.

[23] Jeffrey Lenorovitz, "Europeans Making Plans to Meet Long-term Goals?" *AW&ST,* Mar. 9, 1981, p. 88.

[24] Peter Marsh, "What Shou Id Europe Do in Space, " *New Scientist,* Jan. 29, 1981, pp. 290-292.

[25] Massimo Trella, "ESA Policy Directions—Collective Versus National Programmed," paper delivered at International Aerospace Symposium, Le Bourget, France, June 2-3, 1981.

[26] Michel Bignier, "Expectations for the Future," International Aerospace Symposium, Le Bourget, France, June 2-3, 1981.

[27] For details, see *United States Civilian Space programs, 1958-78,* report by Science Policy Research Division, Congressional Research Service, for the House Committee on Science and Technology, January 1981, pp. 839-841.

memoranda of understanding, are made with U.S. Department of State (DOS) concurrence, while letter agreements require no DOS action whatever.)

In the field of applications the cooperative record is somewhat more mixed. Serious strains arose when, in 1972, the United States withdrew a previous offer for the Europeans to produce a "Space Tug" as part of the Space Transportation System (see app. G). Further mistrust was aroused when the United States backed out of the Aerosat program in 1977. Aerosat was a combined ESA/ U.S./Canadian project to develop an experimental air traffic control satellite system. Beginning in 1974, ESA and other partners invested considerable time and money only to have the Federal Aviation Administration (the U.S. participant) withdraw because of its inability to fund further development.

A third example is the recent deletion of the U.S. spacecraft from the joint International Solar Polar Mission (ISPM). Though ISPM is a scientific, not an applications project, this withdrawal has reinforced European doubts about general U.S. reliability. ISPM was to have involved two spacecraft, one United States and one European, which would simultaneously **fly** over the Sun's "north" and "south" poles. Without U.S. participation, much of ESA'S projected $150 million investment will have been wasted; nevertheless, the U.S. spacecraft was eliminated in Reagan administration cuts implemented in February 1981. Though ESA objected vigorously and member states protested at the ambassadorial level, additional funds were not appropriated.[28] These U.S. actions have raised questions about whether ESA can afford to trust future U.S. commitments, given the vagaries of annual executive and congressional budget decisions and the dependent position of ESA in most projected cooperative projects. Despite these problems, preliminary talks have begun on possibie major areas of future cooperation, including joint processing experiments, possible expansion of Spacelab into a modular free-flying platform, and joint development of a manned space station based on Spacelab modules.[29]

In general, the advantages of cooperation tend to diminish when the project requires much direct contact on a day-to-day level; it is preferable for work to be done as independently as possible, to avoid time-consuming joint decisions. A second difficulty with cooperation in space applications is that the prospect of eventual commercial competition between partners can cause suspicion and reduce its attractiveness to industrial participants.JO

Despite these difficulties, international cooperation was strongly stressed in Massimo Trella's June address, particularly for high-risk, high-expense programs: "ESA **intends to take the initiative in this direction in order to explore with all interested partners how a wider and** more ambitious international cooperation could be defined and implemented in a strategic R&D program me in space in the next decade."[31] It should be noted that the United States is not specifically mentioned; ESA has so far not engaged in cooperative programs with the Soviet Union, though some tentative offers were once made without success. Other European countries, notably France, have done so and it cannot be ruled out that ESA, partly out of frustration with U.S. unpredictability, may seek out the Soviets despite the difficulties involved in collaborating across the iron Curtain,

Competition

Although the total European civilian space budget is only a fraction of either U.S. or Soviet expenditures (Europe spends only 0.04 percent of its gross national product (GNP) on space to the United States' 0.2 percent), the areas in which European technology is commercially competitive with the United States are significant and growing. The competition from Ariane is perhaps most striking, insofar as launch vehicles are the true symbols of space capabilities and were for so long a U.S.-Soviet monopoly. Perhaps equal-

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[28] Jeffrey Lenorovitz, "ESA Seeks Reinstatement of NASA Solar-Polar Effort, " *AW&ST,* Mar. 2, 1981, pp. 22-23; statement of Eric Quistgaard, Senate Commerce Committee hearing, Mar. 25, 1981, pp. 1-5.

[29] " Coming Next–A European Base in Space, " *New Scientist,* Nov. 51981, p. 356; see also Craig Covault, "NASA Mulls International Effort on Space Station, " *A W&ST,* Mar. 1, 1982, p. 20.

[30] " U.S.-Europe Collaboration Variable, " *AW&ST,* Sept. 1, 1980, p. 275.

[31] Trella, "ESA Policy Directions, " p. 7.

equally significant, however, are European successes in gaining contracts from INMARSAT and Arabsat for communications satellites, and plans to bid for future generations of INTELSAT satellites as well. The French SPOT remote-sensing system (discussed below), is scheduled to offer an alternative to U.S. Landsat data beginning in 1984. Though it can be argued that some of the European success may be attributed, not to superior technology, but to the desire of international organizations and non-U. S. purchasers to decrease their dependence on the United States, it is clear that European systems are in many cases equivalent, if not superior, in capabilities and cost effectiveness. However, U.S. objections that European space technologies, in particular Ariane, benefit from unfair financial practices, such as government-subsidized below-market financing for users, are likely to lead to strains between the U.S. and European agencies,

European success, despite lower expenditures, is related to several factors:

- focus on relatively few high-opportunity areas;
- assimilation of U.S. technology in key areas, avoiding unnecessary duplication;
- sustained support by the major countries, particularly France and West Germany; and
- the ability to compromise when necessary, founded on a strong perception that building and maintaining an industrial base in space technology is necessary for Europe's long-term economic vitality.

Though decisions made through ESA may take more compromise and negotiation than comparable U.S. program choices, they are less likely to be precipitously changed or canceled; the government-to-government character of agreements gives them considerable weight. As long as these conditions remain in effect, the United States can expect a high level of competition from ESA and its member states.

EUROPEAN NATIONAL PROGRAMS

In addition to their participation in ESA, which for most countries constitutes the bulk of their space spending, several European states have substantial separate national or bilateral programs. The activities of France, West Germany, Britain, and Italy are of particular interest.

France

The French space program is the largest and most comprehensive in Europe and the third largest in the world, after the United States and Soviet Union. The French have major programs in space science, applications, and launch vehicles. Activities are carried out in several ways: on a national basis; bilaterally with West Germany, other European countries, the Soviet Union, the United States and several third world countries; and multilaterally through ESA.

The French program has been characterized by: 1) an ongoing commitment to developing a comprehensive and independent space program while avoiding dependence on the United States or U. S. S. R., particularly for launch services; 2) extensive cooperation between government agencies and industry; and 3) the development of military capabilities associated with France's independent nuclear deterrent, including ongoing relationships between civilian and military programs.

The decision to cooperate with both the United States and the Soviet Union is indicative of France's longstanding desire to mediate between East and West and to avoid exclusive dependence on either superpower. The idea of France as a "third Force," separate from the United States and NATO **(which France partially withdrew from in 1959), was strongly promoted by DeGaulle, who came to power in 1958. DeGaulle saw France as the natural leader of a resurgent Europe, and hence encouraged the formation of (presumably French-dominated) European multilateral associations. Space was an arena** in which the French felt Europe needed to compete;

France was a major supporter of ESRO and ELDO (particularly the latter) and, eventually, of ESA. (For a description of France's initial space activities, see app. G.) In 1964, out of a total civilian space budget of $76.8 million, France spent $29.6 million on ELDO, and $1 million on ESRO. In 1975, the first year of ESA'S existence, $133 million out of a total of $254 million, or better than **50** percent, went to ESA,[32] and in 1981 France was ESA'S largest contributor with approximately $211.5 million, or 25.06 percent of ESA'S total budget (largely for the Ariane).

However, the percentage of CNES'S budget going to ESA, as opposed to national and bilateral programs, has dropped in recent years as ESA spending has slowed and a number of bilateral and national projects have begun to take shape. The total 1981 budget is Ffr 2,617 million, 37.2 percent larger than in 1980; national programs, however, are up 107 percent at 344.82 million, and bilateral expenditures increased by four times to Ffr 487.52 million.[33] In 1982, CNES plans to spend 82 percent more on national programs, within an overall budget that will increase by 18 percent.

The CNES budget comes primarily from the Ministry of industry and other civilian ministries; in 1981 Ffr 192.8 million came from the Ministry of Defense, while Ffr 596 million came from CNES'S own resources.[34]

Current Applications Programs

COMMUNICATIONS

France is currently involved in three major satellite communications programs. The first is a longstanding experimental bilateral effort with West Germany called "Symphonic," the two satellites of which, launched in 1974 and 1975, are still partially active. Each Symphonic is a geosynchronous satellite with a capacity of 200 telephone or 2 TV plus 18 telephone channels. Symphonic 1 and 2 were built by a consortium (CIFAS) made up of French and German companies and launched by the United States (after some objections regarding possible conflict with INTELSAT–see app. G).[35]

France and West Germany are currently engaged in another joint project for direct television broadcasting, with each country operating its own 3-channel satellite for domestic purposes. The satellites, designated TDF-1 for France and TV-Sat for Germany, are being developed by the Munich-based Eurosatellite Corp., made up of two French firms, Aerospatiale and Thomson-CSF, and two German ones, Messerschmitt-Blohm-Bolkow and AEG-Telefunken. The French contribution for development (divided between CNES and government communications agencies) is estimated at Ffr 980 million; the satellites are scheduled for Ariane launch in late 1984 and eariy 1985.36

The DBS joint effort was an outgrowth of a previously described ESA experimental communications project, H-Sat, which was initially backed by France, West Germany, and Italy. However, in 1978 France and Germany withdrew because of concern over the slow pace of H-Sat development. In particular, the two countries wished to compete in the foreseen European and global market for DBS satellites and groundstations, which they saw as expanding rapidly in the 1980's. An operational system was felt to provide greater economic opportunities than another experimental system. The agreement to develop TDF-l /TV-Sat was signed in 1979.37 **In addition to allowing it to enter foreign markets, French national television estimated that direct broadcast would enable it to provide 100 percent coverage of the entire country for less than half the cost of building additional terrestrial relays.**

Another cooperative venture is the SARGOS project, part of a joint U.S./Canadian program called SARSAT designed to provide emergency search and rescue for ships and planes. France is supplying three SARGOS units to fly on the U.S. NOAA E, F and G satellites. SARGOS is an outgrowth of another project, ARGOS, for collect-

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[32] *World-Wide Space Programs,* p. 168.

[33] " Space Still a Growth Industry in France," *Interavia,* May 1981, p. 406.

[34] " Budget and Programs of CNES for 1981," CNES, p. 3.

[35] *World-Wide Space Activities,* p. 161.

[36] "Space Still a Growth Industry in France, " p. 406.

[37] See "The French Space Effort, " *Interavia,* June 1979, p. 51 O; also Roberto Grandi and Giuseppe Richeri, "Western Europe: The Development of DBS Systems," *Journal of Communication, v. 30,* spring 1980, p. 176.

ing and processing meteorological data from remote platforms, i.e., ballons, buoys, etc. The total French contribution in 1981 to both programs was Ffr 24.7 million.[38]

France is also engaged in a major national communications satellite program called Telecom 1 which is being funded by the Direction Generale de Telecommunications, with CNES project leadership, for a projected 1983 launch. Telecom 1 will provide domestic telephone and telex services within France as well as between France and its overseas territories, including some military traffic. A major use will be in providing internal business communications similar to those planned for the U.S. Satellite Business Systems Corporation .39

REMOTE SENSING

Since 1978, CNES has been engaged in a national program (with some support from Belgium and Sweden) to develop an operational land remote-sensing system called SPOT (Systeme Probatoire d' Observation de la Terre). Through the prime contractor, Matra, CNES is designing a two part satellite consisting of a multipurpose bus with power-supply and stationkeeping systems, and a sensor payload that can be altered as the system develops. The SPOT satellites will be placed in Sun-synchronous 832 km orbits designed to provide 26-day repetitive coverage of the entire Earth. **The initial design calls for two** types of coverage: 1) multispectral observation with 20 m resolution, and 2) black and white observation with 10 m resolution. (This compares with Landsat 3's multispectral resolution of 80 m, and Return-Beam-Vidicon of approximately 30 m). Both of SPOT's instruments can be pointed by remote control so as to cover any area of interest within a path 950 km wide; each individual swath is 60 km in width. This pointing capability makes it possible to provide semistereoscopic images, i.e., successive views of the same area from different angles, which are particularly useful for mapmaking and geological interpretation. It also allows for viewing a particular region more often than once every 26 days; such frequent coverage is necessary for agricultural purposes.

The SPOT images are produced by a linear array "push-broom" scanner that produces a continuous picture 60 km wide on the ground. The images are transmitted digitally from the satellite to ground receivers or they can be stored on tape recorders for delayed transmission. The central receiving and control station is located at Toulouse in southern France. Other countries will be able to build their own stations, subject to agreements directly with CNES; or, data and processed data products will be purchasable through Spotimage, a joint government-industry organization being set up to market SPOT services. In many respects Spotimage will be similar to the previously described Arianespace; CNES will hold 34 percent of the company's shares, with the remainder split between various French firms and government agencies.[40] SPOT transmissions are designed to be compatible with the U.S. Landsat and Landsat-D receiving stations, so that countries that already possess receivers for Landsat will be able to receive SPOT, with some adaptation,

Though each SPOT satellite has a design life of only 2 years, the system is planned to operate for at least 10 years, so that users can count on continuity of data for long-term remote-sensing programs. After the initial launch, scheduled for April 1984, additional satellites will be orbited to ensure continuous service. These satellites will be financed partly by Spotimage, and partly by CNES through its revenues from foreign receiving stations.[41]

The basic reasons for France's decision to build its own remote-sensing system are similar to those for its other space applications projects. These include: 1) to encourage national high-technology enterprises; 2) to gain independence from the U.S. civil remote-sensing system, Landsat, and to demonstrate French equivalence to U.S. and Soviet capabilities; 3) to reap the economic and political benefits of providing global coverage to other countries; and 4) to develop an indigenous remote-sensing capability for military purposes.

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[38] " Budget and Programs of CNES for 1981 ," p. 23.

[39] " Space Still a Growth Industry in France, " p. 406.

[40] "French Marketing Services of Spot Satellite Network, " *AW&ST,* Jan. 11, 1982, p. 99.

[41] See "SPOT—Satellite-Based Remote Sensing System, " CNES brochure, 1980; Jean-Pierre Fouquet, "The SPOT Satellite, " paper presented at 19th Goddard Symposium, Washington, D. C., Mar. 26, 1981.

In line with this last motivation, a military reconnaissance version of SPOT, **known as SAMRO, is already being evaluated. SAMRO would use the SPOT bus, but with higher resolution** optics and secure communications links. Such a satellite would give France the ability to monitor military activities around the world on a continuous basis.[42]

The success of SPOT in gaining a large share of the global market will depend on several factors. First, how advantageous will users view SPOT's 10 to 20 m resolution, as opposed to Landsat-D's 80 m (MSS) and 30 m (TM)? Some users, particularly agricultural ones, will find the increased resolution helpful, while others may find it unnecessarily precise. One of the often mentioned reasons for SPOT's **high resolution is to make it attractive to European agricultural observors,** since European farms are typically smaller than U.S. or Soviet ones.[43] However, some countries may be concerned that SPOT's high resolution will provide foreign users with too much information. Political agreements on restricting dissemination of SPOT data may be required to avoid opposition from a number of states, and Spotimage has announced that it will abide by agreed-on international regulations regarding data dissemination.

The second and probably most important question is the status of competition from other remote-sensing systems, particularly the U.S. Landsat D and proposed D' satellites, which are planned to be operating at approximately the same time (see ch. 3).

SPOT remains unproven both technically and **institutionally.** However, the commitment to a long-term operational status through a private corporation, Spotimage, will help greatly in giving SPOT the credibility it needs to attract customers. In particular, worries about the continuity of the system (which are evident among Landsat users on account of Landsat's currently unresolved budgetary and institutional problems) should be much less than with Landsat. Spotimage plans to provide an across-the-board range of services, including the provision of baseline data for further processing; processed data products for specialized purposes; and aid, advice, and equipment for potential customers. As with Landsat, users can arrange directly with CNES to receive, archive, and distribute SPOT data through national or regional receiving stations. A smoothly functioning corporate entity, especially one heavily backed by the French Government, would provide strong competition to any future U.S. system.

A key question will be the prices charged by both SPOT and Landsat D-D'. Landsat prices are currently government subsidized and in no way reflect the true costs of developing, constructing, and operating either the ground or space segments. **If Landsat or any equivalent is run by a private firm, the prices for clata would have to** rise to reflect these costs. Spotimage prices, though not yet established, will also be substantially higher than those paid by today's users; however, it is not likely that either the U.S. or French governments, having invested heavily to build a prestigious remote-sensing system, would allow the other to substantially undercut its prices for equivalent service. To maintain a market share of commercial buyers, as well as the political gains of supplying data to third world and other countries, each operator will need to keep prices competitive with the other. Whether these prices will be heavily subsidized for political and public-service reasons, as at present, or come closer to reflecting the true costs of land remote sensing remains to be seen; all such decisions will depend at least as much on political as economic factors, including possible competition from future Soviet and Japanese systems.

MATERIALS PROCESSING

French MPS activities, at this time, are modest in scope, with a budget of approximately $1 million to $2 million per year. Bilateral materials processing experimentation agreements are in effect with Germany and the U.S.S.R. A Franco-Soviet crystal growth and solidification experiment was carried out aboard the Soviet manned laboratory, Salyut-6, and future cooperative MPS research is anticipated. In addition, French ex-

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[42] **" France Studies Reconnaissance Version of SPOT Spacecraft,"** *AW&ST,* **Aug. 10, 1981.**

[43] See "The French **Space Effort, "** *Interavia,* June 1979, P. 508.

periments on crystal growth and the dynamics of metal alloy solidification are planned for Spacelab 1 and 3.

In general, the French effort is smaller and more research directed than German activities. CNES has funded a major study, however, on an ambitious program called "Solaris," an unmanned orbital space station which would be able to conduct MPS experiments and could be made available during the 1990's. Solaris would be orbited by an Ariane-4 launcher, operating for a lifetime of up to 15 years. Among its many purposes, the Solaris could serve as an automated orbital materials processing station, handling up to 2 tons of materials in its furnaces. Feedstock would be transported to the station by Ariane-launched unmanned spacecraft. Modules containing processed materials would be returned to Earth from Solaris via unpowered reentry vehicles. The project is still in the conceptual stage and no cost figures are currently available. It is conceivable that Solaris might be accepted as a major project for ESA during the 1980's, thereby spreading the costs and stimulating MPS research activities in a number of member countries not presently pursuing such investigation. Solaris not only represents a major potential French initiative utilizing the Ariane launcher, but is a direct challenge to the U. S./ESA and Soviet manned laboratories (Spacelab and Salyut, respectively) which currently plan materials-processing activities. CNES plans to study manned facilities before deciding on a space-station concept.

LAUNCHERS

The Ariane and its future development have been discussed previously. Among additional possibilities mention should be made of the Hermes manned reusable shuttle, a proposed 22,000-lb, 5-man vehicle that might be launched by the advanced Ariane V. Though only in a very preliminary design stage, the Hermes plan shows that the French have by no means resigned themselves to a completely unmanned role in future space activities.[44]

FOREIGN COOPERATION/COMPETITION

Aside from ESA, France has major bilateral cooperative programs with West Germany, the Soviet Union, and the United States; it is the only country besides India to deal extensively with both the major space powers. In 1981, France budgeted Ffr 379.8 million for German projects, almost all for joint TDF-1 /TV-Sat development. Thirty-seven million francs were spent with the United States, largely for the ARGOS/SARGOS project described above, and for upcoming experiments on Spacelab.

Of the 56 million francs earmarked for projects with the Soviet Union, none are for applications projects per se.[45] However, the fact and extent of cooperative projects are politically significant in themselves. Furthermore, in light of the historical problems with U.S. commitments, it is clear that the French see access to Soviet launchers and facilities as a potential hedge against U.S. delays and vacillation. The most visible of upcoming France-Soviet ventures will be the scheduled 1982 visit of a French astronaut to the Soviet's Salyut 7 (or a reactivated Salyut 6) space station. Two French candidates have been training in the Soviet Union since September 1980.% The Soviets have made a practice of launching non-Soviets for brief orbital stays; to date, however, all such visitors have been from "fraternal Socialist countries," and the flight of an astronaut from a major Western power can be expected to provide the Soviets with a great deal of favorable publicity.

The French national space program, working closely with French industry, will be a major source of commercial competition for the United States in the 1980's. French competitiveness is the result of several factors:

- technically advanced programs in commercial areas such as DBS, land remote sensing, and launch vehicles;
- establishment of institutions (Arianespace, Spotimage) to market systems aggressively on a global basis;

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[44] "The French Space Effort," *Interavia,* June 1979, pp. 508-509; "Solaris: France Proposes Large Unmanned Space-Processing Platform," *Interavia,* May 1981, p. 822.

[45] "Budget and Programs of CNES for 1981 ," CNES, p. 23.

[46] "French Cosmonauts Training for Mission With Soviets," *AW&ST,* Dec. 21, 1981, pp. 55-56)

- close government-industry collaboration as an accepted feature of French commercial practice;
- long-standing government commitment to building space capabilities on a par with the United States and Soviet Union; and
- support received through agreements with ESA and bilateral partners.

West Germany

The bulk of West Germany's space efforts are conducted in association with ESA or bilaterally with other countries. Germany is one of ESA'S major supporters, supplying almost one-fourth of its annual budget. The Ministry for Research and Technology (BMFT) coordinates and funds most German R&D efforts; projects are managed by the German Research and Test Establishment for Aeronautics and Space Flight (DFVLR), which manages Government engineering and test centers, and by the German Research Association (DFG), a self-governing organization that allocates funds from various public and private sources to universities and scientific societies.[45] Space-related expenditures in fiscal 1981 amounted to $371 million, of which $82 million went to DFVLR. Total funding from 1978 to 1982 is projected to be $1.7 billion .48

Germany's major aerospace firms also play a key role in initiating and funding research projects; these include Messerschmitt-Bolkow-Blohm (MBB) and VFW-Fokker, which recently merged, and several large electronics firms such as Siemens and AEG-Telefunken.

Unlike France, Germany has never aimed at achieving an across-the-board set of space capabilities, but rather at encouraging an indigenous aerospace industry, promoting potentially valuable scientific and industrial research, and supporting European efforts in various applications areas. Compared with France there has been greater emphasis on industrial and university initiatives and participation, with Government coordination through the Research Ministry. Despite—or perhaps on account of—the extensive German experience acquired during World War II, there have been no attempts to produce a German launcher, although Germany has been a major contributor to Ariane. Instead, Germany has launched numerous orbital and suborbital payloads on U. S., French, Swedish, and British rockets. The first German scientific satellite, called Azur, was launched by the United States in November 1969.

Applications Programs

Almost all of Germany's efforts in communications and remote sensing are being conducted through ESA or bilateral projects with France, described previously. In 1981, West Germany will provide the largest single share of ESA'S expenditures for Meteosat, OTS, ECS, and Spacelab.Ag

In addition to communications, Germany's strongest emphasis has been placed on materials science and processing. Since the German firm ERNO (a subsidiary of VFW-Fokker) is the prime contractor for Spacelab, and Germany is the major financial contributor (64.78 percent in 1981), German interest in Spacelab exploitation has been high. In addition, chemicals and materials processing have traditionally been areas of German technical and industrial leadership. The Ministry of Science and Technology provided approximately $57 million for MPS work from 1978 to 1980 and is authorized to spend $50 million more between 1982 to 1985. Additional funds are available from non-Federal sources. so

The German MPS program is intended to meet the as yet largely undefined needs of the user community. The ultimate goal of Government support is substantial involvement of German industry in such areas as chemistry, process technology, metals, composite materials, and crystals .51

Early West German experiments were carried on the 1975 Apollo/Soyuz manned mission. A

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[47] " Review of National and Co-operative International Space Activities for the Calendar Year 1980," UNCOPUOS, A/AC.105/286/ Add. 1, Feb. 19, 1981, pp. 34-35.

[48] "Foreign Materials Processing Expenditures," internal NASA staff paper, May 1, 1981, p. 1.

[49] *Europe's Place in Space*, ESA, January 1981, p. 9.

“”’ Foreign Materials Expenditures, " p. 2.

[51] *Commercialization of Materials Processing and Manufacturing in Space*, position paper prepared for OTA by TRW, Inc., Apr. 14, 1981, p. 25.

variety of methods are now being followed, using suborbital sounding rockets, small self-contained payload packages (so-called "Getaway Specials") attached to the space shuttle, and full-scale Spacelab missions. Future flight opportunities using "free-flying" automatic experimental units for longer periods of time than can be attained with the present shuttle/spacelab system are also being examined. Primary elements of the German MPS Program are:[52]

- TEXUS (technological experiments under microgravity): Using British-built Skylark sounding rockets, certain experiments are being flight tested in advance of future Spacelab missions. Five TEXUS flights have been accomplished since 1977, and two launches per year are planned starting in 1981. TEXUS flight results to date indicate this approach is scientifically and technologically useful. West German experiments have also flown on U. S. SPAR sounding rockets.
- MAUS (materials science autonomous experiments under zero-G conditions) program: Instruments partially based on TEXUS program findings are to be carried in 25 German-purchased getaway special canisters. These autonomous packages provide experiments with much longer microgravity duration than attainable with sounding rockets.
- Spacelab: Germany is supporting major experiments on Spacelab, including a materials processing laboratory to be flown on Spacelab 1 in mid-1983. Materials science experiments will be conducted in the materials science double rack, a largely German contribution to the first Spacelab mission. The facilities include the following: 1) high-temperature thermostat, 2) mirror heating facility, 3) isothermal heating facility, 4) capillarity measurement equipment, 5) cryostat, 6) fluid physics module, 7) gradient heating facility, 8) UHV chamber, and 9) common support equipment.

  A wholly German Spacelab mission, the D-1, is now scheduled for September 1984. The D-1 will carry the Biorack for investigations of cell and molecular biology, and an advanced fluid physics module. These will perform a mixture of open experiments, for which data will be freely disseminated, plus a number of closed experiments with potential commercial benefit. For these latter, Germany has proposed to pay a pro rata share of the normal Spacelab users' fee; the exact financial arrangements have not been concluded. Prime objectives for the mission are experiments in the fields of metals, monocrystals and materials for electronic applications, boundary layer and transport phenomena problems, and physical chemistry and processing.

The German program stresses involvement with the industrial sector in addition to purely scientific exploration. The Ministry of Science and Technology is working closely with both MAN, Inc., and Volkswagen. The work at MAN involves "skin technology"; this is a process by which complex refractory metal alloys used for turbine blades can be melted and resolidified in space with an oxide skin, which is a plasma sprayed on the surface of the container. New immiscible metal alloys for potential use as bearing materials are of interest to Volkswagen. sq

Although the German Government has not supported any launcher-related programs, aside from Ariane, mention should be made of a private German firm called OTRAG (Orbital Transport-und-Raketen Aktiengesellschaft), which has spent $65 million to $70 million since 1974 trying to develop a mass-produced expendable rocket for inexpensive satellite launches. To date, OTRAG has claimed four successful test flights and until recently planned to launch its first orbital flight in 1982.[54] OTRAG hopes to attract private firms and third world countries by providing relatively simple services at prices that Ariane and, the space shuttle cannot match. The rockets would use off-the-shelf components and an extremely cheap fuel made of diesel oil and nitric acid.

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[52] See G. Greger, "Science and Technology of the German MPS Missions," paper presented at 1980 AAS Annual meeting, Boston, Mass., Oct. 20-23, 1980.

[53] TRW paper, op. cit, pp. 25-26.

[54] "German Company Testing Launch Vehicle in Libya," *AW&ST*, Mar. 23, 1981, p. 25.

The political controversy surrounding OTRAG has been intense, largely as a result of the location of its test facilities. Until 1979, OTRAG operated out of a 39,000 mi^2 area in Zaire, where it had agreed to pay the Mobutu government $50 million per year or 10 percent of gross revenues, whichever was greater, once commercial operations commenced.[55] However there were numerous protests, not only from Zaire's neighbors, who feared the rockets might have military uses, but also from the Soviet Union, which was intensely concerned at any evidence of German development of an independent launch capability. The German Government was embarrassed and tried various means to put OTRAG out of business, including passage in 1978 of the so-called "Lex OTRAG" prohibiting the export of OTRAG rockets or components. Eventually international pressure forced Zaire to expel OTRAG; however, the company soon relocated its test facilities in Libya, partly, according to OTRAG president Frank Wukasch, because Libya's ruler Muammar Qaddafi "cannot be blackmailed" into expelling the company.[56] OTRAG'S presence in Libya reinforced fears that its missiles might be used for military purposes, perhaps against Israel. Recently, it was reported that OTRAG had withdrawn from Libya and would seek new facilities, perhaps in India or South America.[57]

COOPERATION/COMPETITION WITH THE UNITED STATES

The German attitude towards cooperative ventures with the United States has generally been more positive than the French, as shown by German willingness to take the lead in building Spacelab. A large number of cooperative space science projects are also underway. Cooperation with the Soviet Union has been negligible for political reasons.

Though there are few major areas where German projects will directly compete with the United States, German aerospace and electronics firms have been strong competitors for component and subsystem contracts on INTELSAT and other communications satellites. The Research Ministry is particularly interested in expanding German capabilities in this area.[58] The experience gained in ESA communications projects and particularly through joint TV-Sat development with France will give German industries the ability to compete for complete systems in the emerging DBS market.

Great Britain

During the 1970's British civilian space spending has been done almost exclusively as part of ESA projects. (For a brief description of early British space activities, see app. G). Even within ESA, Great Britain has chosen to concentrate on communications and general science, and has contributed relatively little to ESA'S two largest projects, Spacelab and Ariane. British choosiness has been a function in part of budget restrictions caused by generally poor economic performance compared with its continental partners, and to a fundamental historical uncertainty as to whether to opt for close ties with the United States, with Europe, or with the Commonwealth, Largely because of its traditionally close relationship with the United States, Britain has not favored development of a European launcher, whether the Europa or Ariane, considering it uncompetitive and unnecessary. With a strong university research base and relatively weak industries, Britain has preferred to concentrate on basic science and on a few areas, especially communications, in which British firms such as Marconi and British Aerospace could hope to become internationally competitive. In general, the above constraints have made the formulation and implementation of any coherent space policy very difficult. There is little public or political consensus as to Britain's proper role in space activities, and the major political parties often fail to follow through on initiatives begun by their predecessors. A September 1980 memorandum by the British Royal Society, which proposed establishing a National Council for Space, pointed out that: "The present U.K. efforts in space science and technology are fragmented and there is a serious lack of

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[55] A *W&ST*, Sept. 12, 1977, p. 42.

[56] Bradley Graham, "Rocket Firm's Third World Ties Test Bonn's Patience," *Washington Post*, Aug. 14, 1981, p. 17.

[57] "Otrag Ends Libyan Launch Work," *A W&ST*, December 1981.

[58] "West German Space Program, " *Interavia*, April 1980, p. 312.

cohesion to such an extent that there appears to be no overall domestic space policy."[59]

Organization and Funding

Government responsibility for space has been split between several organizations. The Department of Trade and industry has funded civilian programs, while the Space Research Council, part of the Department of Education and Science, has supported scientific projects, including cooperative ventures with ESRO and NASA. The Post Office (now British Telecom) has operated communications networks including INTELSAT receiving stations.

In 1972, the total budget was $55.1 million, of which $15.5 million went to ELDO and ESRO. By 1976, the budget had risen to $80,2 million, all of which was spent within ESA.[60] In 1981, Great Britain was ESA'S third-largest contributor with 14.88 percent of the total budget, amounting to $125.6 million, and was the majority contributor to the Marecs ocean communication satellite program.[61] Present plans call for a substantial increase in space spending, with emphasis on nationally funded communications satellites.[62]

Current Applications Programs

The area in which the British have been most active over the past several years is communications satellites. Within ESA, British Aerospace (BAe) has been the consortium leader for the OTS, ECS, and Marecs systems, and Britain was the prime mover behind ESA'S decision to develop the experimental L-Sat multipurpose communications platform. In addition, there has been considerable activity by British agencies and private firms, spurred by the Thatcher government's recent decision to open up private competition in telecommunications by removing British Telecom's monopoly over network operations.[63] In June 1981, BAe announced formation of a company called Satellite Broadcasting Co., Ltd., to provide common carrier DBS services. Two satellites plus a ground spare would be required at an estimated cost of L100 million; services would be leased to British broadcasters such as the BBC and Granada television.

Another possible venture would involve BAe and IBM in a business communications service, similar to the newly created U.S. Satellite Business Systems, of which IBM is a major partner. It is not clear whether such a plan could succeed within Britain alone, and expansion into the European market, with the attendant difficulties of operating across national boundaries, may be envisioned.[64]

In a somewhat different field, BAe and Marconi have joined forces, after pressure from the Defense Ministry, to build the British Ministry of Defence's proposed communications satellite, Skynet IV/Satcom. Although both BAe and Marconi had initially sought out U.S. industrial cooperation, an all-British program was deemed preferable. Launch is estimated to be in early 1985.[65] British Telecom (formerly the Post Office) is planning its own Europeanwide business satellite system which will make use of nine transponders; two each placed on all four ECSs, and one leased from France's Telecom 1. The eight ECS transponders will cost approximately $150 million. Users will purchase ground stations that will provide access to any point in Europe; the system will be operated through an agreement with Interim Eutelsat.[66]

it is clear that British industry is eager to move into the potentially lucrative areas of DBS and satellite business communications, if necessary in conjunction with foreign partners who can provide financial and/or marketing support. A major question remains as to whether European operations will be possible given prospective competition from Eurosatellite (the manufacturer of TDF-1 /TV-Sat) backed by national PTTs. In addition there are numerous regulatory pitfalls, as well

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[59] *Spaceflight,* British Interplanetary Society, Feb. 2, 1981, p. 33; see also Johnny Hawkes (former Director of Space, Dept. of Industry), "Britain in Space: Time to Consolidate," New Scientist, Jan. 14, 1982.

[60] *World-Wide Space Activities,* p. 222.

[61] *Europe's Place in Space,* ESA, Paris, January 1981, p. 9.

[62] Peter Marsh, "Britain Plans Big Boost for Space Budget," New *Scientist,* Feb. 23, 1982.

[63] Peter Marsh, "Communications in the 1980's—Satellites or Fibre Optics?" New *Scientist,* July 23, 1981.

[64] "BAe Aiming To Become Major Satellite Operator?" *Interavia,* August 1981, pp. 754-755.

[65] "Skynet IV-Now an All-British Military Satcom System," *Interavia,* September 1981, p. 859.

[66] "Satellite Business Communication Comes to Britain," *Flight International,* Feb. 7, 1981, p. 342.

as possible challenges from INTELSAT, if the new services threaten to take business away from the Intelsat system.[67] It is still early enough in the evolution of satellite systems for any number of developments to occur, including joint ventures between British and European companies. BAe recently formed a partnership with the French firm Matra, called Satcom International, to bid on satellite hardware, and similar agreements may be made for services.

Italy

Italy has been a consistent supporter of European space activities and in 1981 contributed 9.94 percent of ESA'S budget, or around $82.9 million. Italy has not taken the lead in any major applications projects, but has chosen to support a variety of programs that would provide Italy's aerospace and electronics industries with contracts for advanced technologies. Difficulties in meeting its financial obligations to the Spacelab program in the face of large cost overruns led Italy to reduce its contribution from 18 percent of Spacelab funding in 1979 to 1 percent in 1981. The recent decision to use Italy's Sirio 2 communications satellite for ESA communications has given Italy the lead role in that project.

Aside from its European multilateral contributions, Italy has maintained a small national program centered around its unique off-shore launch platform, located on the Equator off the shore of Kenya in the Indian Ocean. The San Marcos platform has been the site of numerous small satellite and sounding rocket launches, mostly by U.S. rockets but including British and European ones as well, which have taken advantage of its equatorial position for experimental flights. The first Italian satellite, San Marcos 1, was launched by a U.S. Scout in 1964; subsequent San Marcos series satellites were launched from the San Mar cos platform, also by Scout.

In 1977, Italy orbited an experimental geostationary communications satellite, Sirio 1, on a U.S. Thor-Delta. The ground spare for that project, Sirio 2, will be launched in April 1982 by ESA to disseminate meteorological data; the Italian Compagnia Nazionale Satelliti di Telecomunicazioni is prime contractor on the project.

Unlike all other European states except Portugal, Italy's participation in INTELSAT is done through a private firm, Telespazio, rather than a national PTT. Since 1976, Telespazio has also operated a Landsat receiving station at Fucino.

The Italian space program has suffered from lack of central coordination and public support, as well as the strains of Italy's turbulent economic and political situation. Space activities have been coordinated and funded by the National Research Council (CNR), which began to fund space-related activities in 1960. Other ministries and agencies, such as the Post Office and the Defense Ministry, also play a role. In 1972, Italy spent $19.4 million on space, $9.8 million of which went to ELDO and ESRO; in 1976 this had risen to $60.5 million, almost all in ESA.[68] Recently, the government approved a plan to double Italy's space expenditures over the next 2 years; most of the increase will go to fund national programs. These may include a national communications satellite (Italsat) and a television DBS system, as well as several cooperative ventures with NASA: IRIS, a small booster for the shuttle payload bay; and the so-called "tethered satellite," which is designed to be attached to the shuttle in orbit by a long umbilical cord.[69] Italy has been a strong supporter of ESA'S experimental L-Sat communications platform, and will use one of the first satellite's 2 TV-channels for direct television broadcasting.

Recently the Italian Defense Ministry has proposed a domestic military communications system, SICRAL, for secure voice and data transmission and for use in civil emergencies. The satellite hardware will be designed and manufactured by Italian firms for eventual launch on either the shuttle or Ariane.[70]

Other European Programs

The space efforts of other countries in Europe have taken place almost entirely within the Euro-

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[67] "Communications in the 1980' s," *New Scientist,* **July 23, 1981.**

[68] *World- Wide Space Activities,* **p. 176.**

[69] **Peter Marsh, "Italy Joins the New European Space Race, "** New *Scientist,* **Apr. 1, 1982.**

[70] **Andrea Lorenzoni, "SICRAL: A Proposed Italian Defence Satellite System,"** *Interavia,* **August 1981, p. 793.**

pean agencies, ESRO, ElDO, and now ESA. A few non-ESA projects, however, deserve mention, particularly the proposed Nordsat regional communications system to provide television and radio broadcasting between Sweden, Norway, Denmark, and Finland. Under discussion since 1972, the system is designed to promote Scandinavian cultural unity–the details, which have been understandably difficult to arrange considering the many countries involved, are not as yet determined.[71] In connection with this proposal, Sweden is developing a satellite, known as Viking, for 1984 Ariane launch; it will investigate magnetospheric conditions preparatory to a possible communications satellite program. Saab-Scania is building the payload, while Boeing provides the satellite bus; Viking will provide Sweden with crucial experience in satellite communications operation, and will also further the Swedish goal of encouraging an indigenous commercial space systems industry. Studies have also been done for a second Swedish satellite, Tele-X, for a variety of experimental communications activities .[72]

Another potentially interesting development is Compagnie Luxembourgeosie de Telediffusion's (CLT) plan to provide multinational direct television programing via satellite by 1985. The company's potential difficulties illustrate the problems faced when operating across European boundaries. CLT is Europe's largest commercial (i. e., nongovernment) broadcaster, covering large portions of France, Germany, Belgium, Denmark, and the Netherlands. Since it is in direct competition with national broadcasters, foreign governments, particularly Germany, have opposed ClT's expansion plans, in part by trying to discourage investment in CLT stock. CLT is proposing a three-channel $250-million satellite that could broadcast simultaneously in French, German, and Dutch, reaching a potential 100 million viewers. Launch reservations have already been made on both Ariane and the Shuttle.[73]

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[71] See R. Grandi, and G. Richeri, "Western Europe: The Development of DBS Systems, " *Journal of Communication,* spring 1980, pp. 175-176.

[72] " Sweden Moves Ahead on Research Satellite," *A W&ST,* Sept. 1, 1980, *p.* 49.

[73] "The No. 1 Broadcaster Fights Back From Space, " *Business Week,* May 4, 1981, pp. 66-67.

JAPAN

Organization and Policy

Japanese interest in space science and technology began in the mid-1950's, when multilateral planning was underway for the International Geophysical Year (1957). Alone among the major space-capable countries, Japan's space efforts were not initially prompted by military concerns. The postwar Japanese constitution specifically prohibited the buildup of large military forces, and public opinion has been consistently opposed to any signs of militarism and to large expenditures for military purposes. Because of the worldwide association of space programs with military capabilities, Japan carefully placed its first space establishment at the University of Tokyo, the country's foremost educational institution. The Institute of Space and Aeronautical Sciences (ISAS) was founded in 1954, and (though it recently became an independent institute) is still responsible today for Japan's scientific programs. Beginning in the late]9s0's and through the 1960's ISAS developed the Kappa and Lambda series of solid-fuel sounding rockets, which formed the basis for Japanese scientific and applications experiments. The difficulties of rocket development were enhanced by inadequate guidance and stabilization technology, which was in turn due partly to a self-imposed reluctance to fund technologies that might give the rockets enough accuracy to be perceived as having military capability.[74] ISAS went on to develop orbital rockets; the first successful 24-kg test satellite was launched by an advanced Lambda, after several years of failure, in February 1970. The Mu-class orbital launcher achieved its first success in 1971 and has been operated by ISAS since then from its Kagoshima test range.

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[74] *World-Wide Space Activities,* p. 185.

In 1960, the National Space Activities Commission (NSAC, later SAC) was established in the Prime Minister's office to give advice on Japan's overall space program. It operates today as a major source of high-level planning, along with the Science and Technology Agency (STA). In 1964, the STA created the National Space Development Center to conduct rocket tests; this was due in part to dissatisfaction with ISAS'S purely scientific orientation. In 1969, this became the National Space Development Agency (NASDA), which is today the principal agency for civilian applications and test programs, launcher development, and tracking facilities.[75] NASDA operates the Tsukuba Space Center near Tokyo, Japan's main satellite test facility, as well as the Tanegashima launch site, located on an island in the south of Japan.

Other space-related activities are conducted by the Ministry of Posts and Telecommunications in satellite communications, and the Transport Ministry, which operates the weather service, in meteorological satellites. A private firm, Kokusai Denshin Denwa Ltd., is responsible for relations with INTELSAT. NASDA cooperates with other ministries and agencies in the research and design of applications programs, as well as conducting launches (see fig. 12).

The Japanese budget for space research was very small, though growing, through the 1960's.[76] With the establishment of NASDA annual funding has increased rapidly, from a total of $23.5 million in 1968 to almost $477 million in 1981. Of this the bulk, almost 80 percent, goes to NASDA, with the remainder split between ISAS and other government programs (see fig. 1 3).

The budget is drawn up by the SAC on a yearly basis. In addition, the SAC prepares long-range comprehensive plans. The latest 15-year proposal, drawn up in 1978, calls for a total 15-year expenditure of$14 billion to fund an across-the-board program in space science, applications, and launch-vehicle development. " The SAC stressed that "Japan should develop the necessary technical capabilities to carry out her comprehensive space program, although it is not necessary to produce everything domestically."[78] Active international cooperation and peaceful development were emphasized as guiding principles,

Current and Projected Applications Programs[79]

Communications

In December 1977, the Japanese orbited an experimental geostationary communications satellite, the CS-Sakura, aboard a U.S. Delta rocket. The Sakura has been used by the Radio Research Labs of the Ministry of Posts and Telecommunications for experiments in 30/20 GHz propagation (the first country in the world to do so), and to gain experience in the control and operation of communications satellites. An operational system consisting of two satellites, the CS-2a and CS-2b, is planned for launch in early and mid-1983, respectively (CS-2b will be an orbital spare); the recently developed N-11 launch vehicle will be used. The satellites themselves were built by a group led by Mitsubishi Electric and Ford Aerospace.[80] The operational system will provide emergency communications as well as links with remote islands; the signals will be receivable by small transportable Earth stations in either K or C band, and will represent the first operational use of 30/20 GHz technology, The satellites will be managed by the Telecommunications Satellite Corp. of Japan, established in 1979.

A parallel program in direct television broadcasting is also being conducted, with the BSE-Yuri satellite launched in April 1978 by a U.S. Delta for geostationary experiments in audiovisual transmission. The operational system, with two satellites, BS-2a and BS-2b, is planned for N-11 launch in early 1984 and mid-1985. The Ministry of Posts and Telecommunications has funded the system, which will enable it to transmit images to mountainous and outlying areas. al

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[75] See *World-Wide Space Programs,* p. 186; also *NASDA 80-81,* National Space Development Agency of Japan, pp. 3-4.

[76] See *World-Wide Space Activities,* p. 204.

[77] "Japanese Commission Proposes Ambitious 15-Year Space Plan," *AW&ST,* Mar. 27, 1978, p. 23.

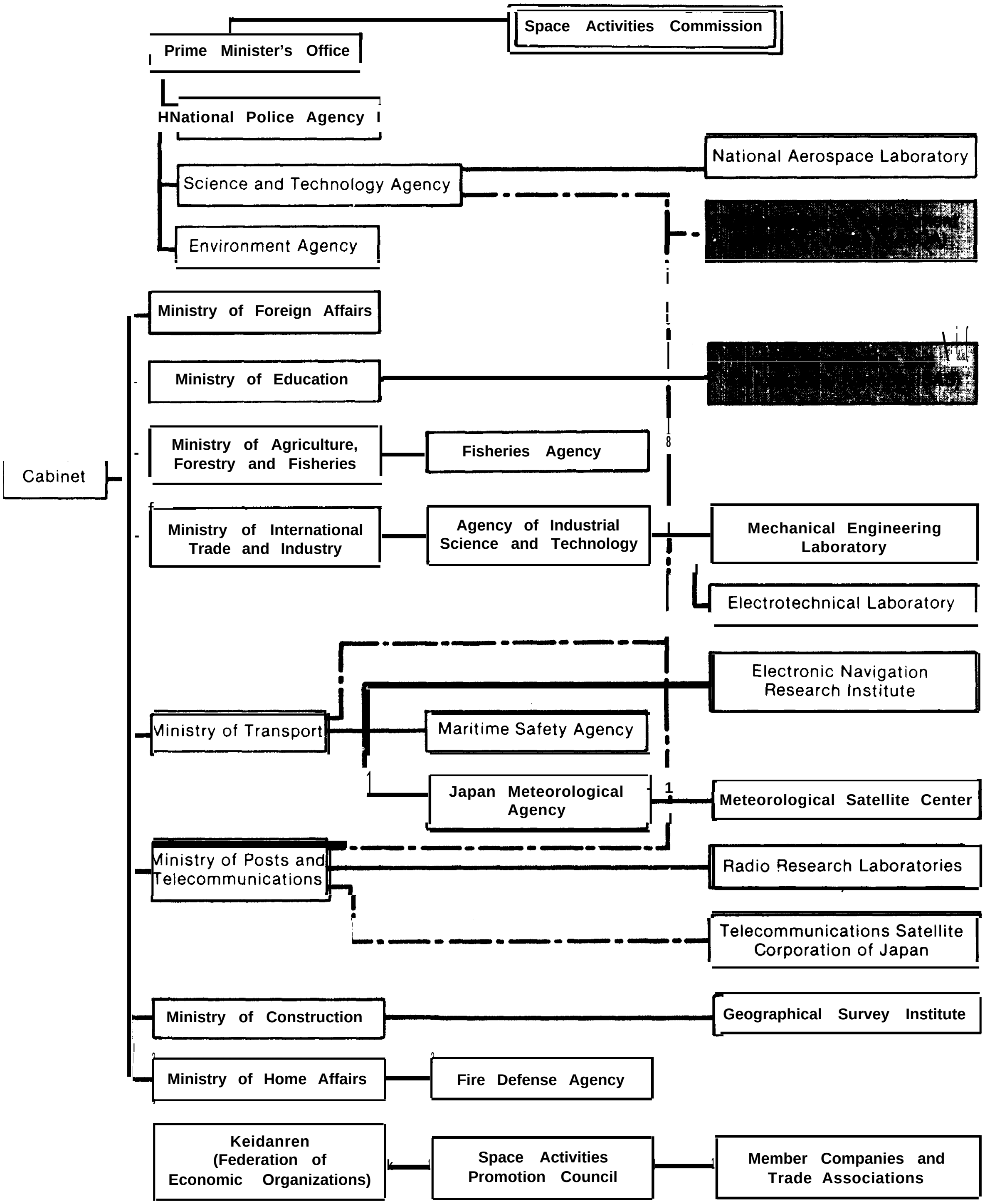
[78] Masao Yoshiki, Acting Chairman, SAC, "Japan's Space program, " paper delivered at International Aerospace Symposium, Paris, France, June 2-3, 1981, pp. 1-2.

[79] Information in this section, unless otherwise noted, is taken from *NASDA 80-81,* NASDA 1980.

"'Japan Gaining Maturity in Satellite Technology," *A W&ST,* Mar. 3, 1980, p. 92.

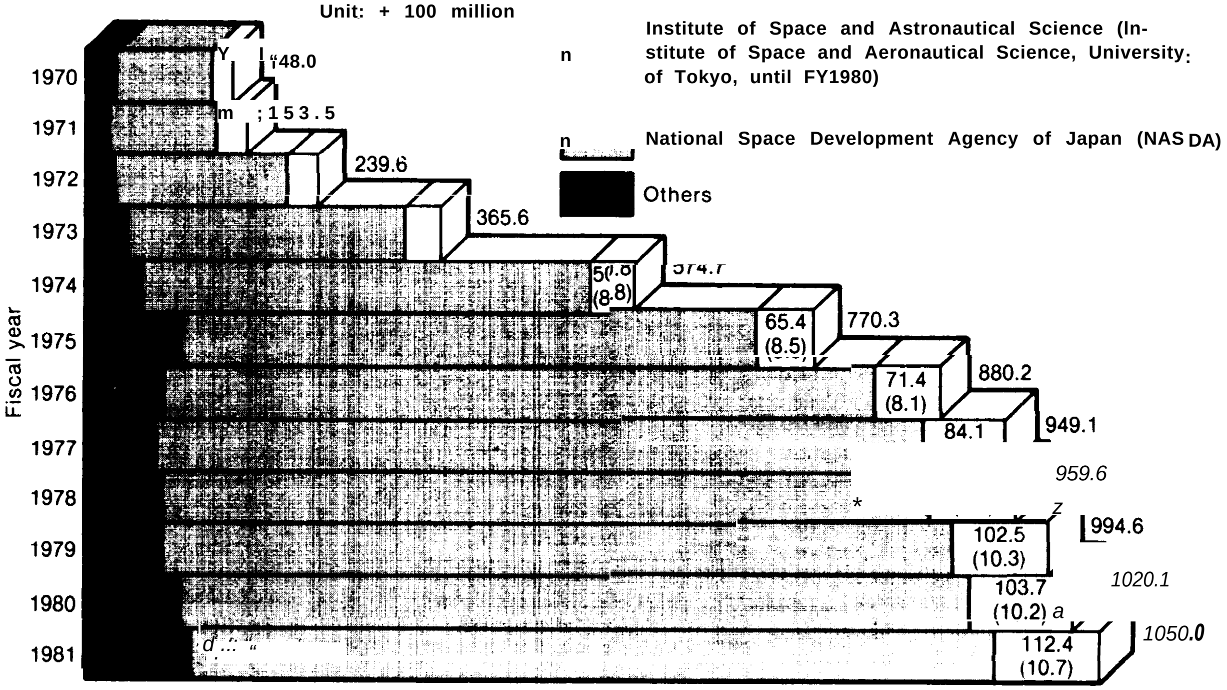
[81] "Japanese Gain Capabilities in Advanced"Space Effort," *A W&ST,* Mar. 9, 1981, p. 109.

Figure 12.—Schematic Chart of National Organization for Space Activities



SOURCE Nat,ional Space Development Agency of Japan

Figure 13.—Japanese Budget for Space Activities[a]



NOTES: 1. The upper figure in each fiscal year shows the total budget for space activities,
2. Figures in parentheses indicate percentage (%) as against the total budget for each fiscal year

a"Space in Japan 1981 -1982," Keldanren, Tokyo, 1981, p. 4 (One dollar = approximately 225 yen, 100 million yen = 444,444 dollars at January 1982 exchange rate,)

SOURCE National Space Agency of Japan

The impetus toward operational development of these systems has come from a desire to develop expertise in the design and operation of communications satellites for commercial/industrial exploitation. Satellite broadcasting is particularly useful for communicating within Japan's mountainous and far-flung territory, which includes many small islands. They were preceded by extensive ground-based R&D during the 1960's, including cooperative experiments with NASA on signals propagation, and the assumption of control over NASA's advanced experimental communication satellite, ATS-1, in 1974.[82]

In connection with Japan's communications program mention should be made of a failed experimental program, the Ayame and Ayame 2 satellites. Designed to further test satellite control and communications facilities, both failed to achieve geostationary orbit when launched in 1979 and 1980 by the Japanese N-1 rocket. The first failure was due to a collision with the third stage motor after separation, the second to an apparent misfiring of the apogee engine. The repercussions from these consecutive mishaps, which cost the Japanese an estimated $100 million, have been great; not only was the chairman of NASDA forced to resign[83] but, more importantly, the Japanese were moved to accelerate their efforts to achieve independence from the United States in space capabilities. Both failures were traced to probable malfunctions of U.S.-supplied equipment. Though in the past the Japanese have relied heavily on the United States, dissatisfaction with U.S. technology can only mean fewer contracts for U.S. firms and more emphasis on indigenous

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[82] *World-Wide Space Activities*, p. 200.

[83] "Two Mission Failures Force Space Official's Resignation," *AW&ST*, June 3, 1980, p. 26.

development and/or deals with European companics.[84]

In the area of ground stations for communications satellites, Japanese firms have long been leaders in the manufacture and sale of INTELSAT compatible stations and subsystems to developing countries. Both Mitsubishi and Nippon Electric have made extensive sales abroad; in addition, Japanese firms have obtained subcontracts from Hughes and other U.S. companies for work on INTELSAT payloads.

Remote Sensing

Japan has the world's largest fishing fleet and depends on the oceans not only for food, but for the transportation of vital raw materials and exports, to a greater extent than any other developed country. In addition, Japan is a frequent victim of typhoons formed in the Central Pacific, where meteorological facilities are poor and thinly scattered. Hence there is a special interest in the development of ocean-monitoring satellites, both for weather prediction and for exploitation of ocean-based resources.

Many of the early sounding rockets were used for meteorological experiments. The first dedicated Geostationary Meteorological Satellite, GMS-Himawari, was launched in July 1977 by a U.S. Delta. Still in operation, it has provided the Japan Meteorological Agency with cloud-images for public dissemination, along with infrared temperature information, and has disseminated data to other countries in the region. Himawari was also Japan's contribution to the World Meteorological Organization's Global Atmospheric Research Program (GARP). A second satellite, GMS-2, was launched in August 1981 on an N-l! vehicle; it was developed by a group led by Nihon Electric and Hughes Aerospace.[85] The GMS-3 is scheduled for launch in the summer of 1984.

Under development is a geodetic survey satellite, GS-1, for a possible launch in 1985. The GS-1 will be designed to be highly reflective, allowing ground stations to bounce lasers off it for measurement purposes.

The most ambitious current program is the Maritime Observation Satellite, MOS-1, which will be Japan's first satellite to provide continuous global Earth observation. It is designed to observe ocean surface phenomena and will include visible, infrared, and microwave scanning radiometers. The primary sensor will be the multispectral self-scanning radiometer, a charge-coupled device (CCD) providing 50-m resolution imagery. Hence MOS will provide operational experience with land remote-sensing data collection and data-processing, comparable to Landsat and Spot. It is currently scheduled for an N-11 launch in August or September 1986.

A proposed follow-onto MOS is the Earth Resources Survey Satellite, ERS-1, a 2,700-lb remote-sensing spacecraft currently in preliminary design. ERS-1 would be launched in 1988 aboard the new large-capacity H-1A launcher. Possible instrumentation includes synthetic aperture radar, stereo camera, and visible infrared measurement systems.[86] The ERS-1 would eliminate Japanese dependence on outside systems such as Landsat and SPOT, and could be used to further the search for foreign sources of energy and other raw materials. In addition, it would allow Japan to compete with these systems for the sale of remote-sensing data and data products. B'

Materials Processing

Japan is cultivating an on-going MPS program as an element of its 15-year space development policy. MPS work in developing alloys, compound materials, electronic materials, and medicines, as well as the life sciences, is going forward with experiments on both the U.S. Space Shuttle and the TT-500-A, a Japanese suborbital rocket:

- TT-500-A; This small two-stage suborbital rocket with recoverable payload sections provides approximately 7 minutes of microgravity (under 1o-4 G), comparable to the U.S. SPAR and German TEXUS. NASDA has

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[84] "Japanese Gain Capabilities in Advanced Space Effort," *AW&ST,* Mar. 9, 1981, p. 108.

[85] "Japan Gaining Maturity in Satellite Technology," p. 92.

[86] "Japanese Gain Capabilities, " p. 107.

[87] "Japan Gaining Maturity," p. 92.

established a space experiment schedule for the IT-500-A of two flights per year. An early 1981 launch carried a metallic compound processing experiment, while an August flight evaluated semiconductor processing techniques.

- ***Space Shuttle:*** NASDA anticipates funding annual missions with Spacelab, inaugurating its use with a first material processing test (FMPT) in fiscal year 1985. The FMPT will make use of half or one-third of the available space in the shuttle-carried Spacelab. A Japanese payload specialist will join shuttle crews to conduct the FMPT and later shuttle-based experiments.[88]

Though the Japanese hope for major potential gains from MPS investments, they do not expect them in the near future. MPS experimentation is seen as a way of insuring a competitive position 10 or 15 years from now.

Launch Vehicles

The Japanese have not had an easy time developing their own launch vehicles. During the 1960's, ISAS was responsible for designing an orbital launcher; after several years of failure a Lambda sounding rocket was able, with the addition of a fourth stage, to launch Japan's first satellite in 1970. The Mu series of solid-fuel rockets was more successful, and the first orbit was achieved in 1971. The Mu launchers have been improved with radio guidance and are used by ISAS for scientific flights. Nissan Motors is currently designing an advanced version, the M-3-kai-l, which will be used for Japan's 1st planetary exploration flights in the mid-1980's, including a planned Halley/Venus mission in 1985.

in 1969, NASDA assumed primary responsibility for launcher development for applications satellites. Instead of attempting to develop further versions of the Mu launcher, NASDA decided to approach the United States for access to technology for the Thor-Delta launcher and licensing arrangements to manufacture parts of the Delta in Japan. The U.S.-Japanese Agreement on Space Activities, signed on July 31, 1969, gave Japan Delta technology, subject to an agreement not to transfer it to any third party. The first flight of the new N-1 launcher took place in September 1975, when an 85-kg test satellite, Kiku ETS-1, was placed in a 1,000-km circular orbit. Basically the N-1 consists of a Thor first stage, built under license in Japan by Mitsubishi Industries; a Japanese developed liquid-fuel second stage; and a U.S. Thiokol third stage. In all, approximately 67 percent of the N-1 is supplied by Japanese firms. The N-1 can lift 130 kg into geostationary orbit; in February 1977, it launched Japan's first geostationary satellite, making Japan the third country in the world, after the United States and Soviet Union, to do so.

An uprated version, the N-11, had its first successful test flight in February 1981. The N-ii can carry 350 kg, or over twice the N-l's payload, to geosynchronous orbit. Mitsubishi Industries is the prime contractor; the major differences from the N-1 are the use of additional solid-fuel strap-on boosters and the replacement of the Japanese-designed second stage by an improved version of the U.S. Aerojet second stage used on the Delta. As a result the Japanese contribution to the N-11 is only 56 percent, less than for the N-1.[89] The N-11 will replace the N-1 by 1983 and is planned for use through the mid-l 980's.

For the latter 1980's and 1990's a new booster design, the H-1A, is under development. The major innovation is a planned liquid oxygen/ liquid hydrogen second stage, to be built by Mitsubishi. The initial version of the H-1A will be able to place 550 kg into geosynchronous orbit; a proposed follow-on version would be able to launch 800 kg. The H-1A will also use an inertial-guidance system instead of the radio guidance of the N-1 series. Projected development costs are $755 million; the first operational flight of the full three-stage rocket is scheduled for 1987.90 The H-1A is necessary for the launch of advanced heavy satellites such as the proposed ERS-1, and will give Japan a launcher roughly equivalent to ESA'S Ariane 1. However, there are currently no plans to market any projected launchers on a commercial basis.

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[88] "Japan's Space Program," p. 16.

[89] "Japanese Gain Capabilities," p. 109; "Japan Gaining Maturity, " p. 96.

[90] "Japanese Gain Capabilities," p. 109.

Japan's launch capabilities have been severely restricted by agreements with the Japanese fishing industry that allow missiles to be fired only at two times of the year, January-February and August-September.[91]

To date the Japanese have no firm plans for developing a manned launched capability; Japanese payload specialists will fly on space shuttle missions during the 1980's, with the first Japanese astronaut scheduled to fly in fiscal year 1985. However, there have been very preliminary designs for a "mini-shuttle" capable of carrying a four-man crew plus 1,100 lb of cargo. Such a vehicle is seen as eventually necessary for full exploitation of the scientific and applications programs currently under way.[92]

Cooperation/Competition With the United States

As is clear from the preceding description of its major applications programs, Japan has in the past worked closely with NASA and with U.S. industry. The transfer of Thor- Delta technology has been the largest single result of that cooperation; in addition there have been numerous scientific exchanges. Many of Japan's applications satellites have been designed in part by U.S. firms engaged in joint ventures with Japanese companies. The Japanese plan to use Spacelab extensively.

At the same time it is clear that the Japanese intend to use the technology and expertise gained through cooperation to build up their own independent government and private sector capabilities. The immediately resulting systems have been developed to meet national and public needs in communications, meteorology, and remote sensing; the major commercial effect has been to begin to remove Japan as a market for U.S. systems and launch vehicles. Eventually, however, there is no doubt that Japan will attempt to export its equipment and services. There is a long and well-known pattern of rapid Japanese entry into foreign markets, following on successful assimilation of imported technology, development of domestic markets, and the mastery of techniques for mass production and marketing. Though most of these successes, as in consumer electronics and automobiles, have not been in advanced-technology areas, the government and industry have recently been emphasizing technically sophisticated products in the belief that Japan must compete there to sustain economic growth through the end of the century. Space technology is definitely a major area of interest, and government and industry have been working closely together to prepare for Japanese entry into world markets.

A recent study undertaken by Japan's influential Ministry of International Trade and Investment (MITI) predicts that by the mid-1 990's space will be a $4.5 billion per year industry (current sales of Japanese companies are $480 million, almost entirely to the government). The study emphasizes not only export potential but technological spinoffs; an indigenous space industry is vital since: "As unilateral introduction of technologies from foreign countries is getting more difficult, it is necesary to strengthen Japan's own bargaining power through accumulation of necessary technological know-how, " Recognizing that Japan is some 5 to 10 years behind the United States and Europeans in key areas, especially launch vehicles, there is emphasis on taking advantage of Japanese strengths in quality control, mass production, and marketing.[93]

Despite the disadvantages of a smaller economic and technical base to draw on than either the United States, Europe, or the Soviet Union, and the lack of major military programs to ensure political and financial support, Japan has succeeded in achieving a position of high technical and industrial competence in the entire range of space activities. Though not yet able to offer full-scale commercial products or services (with the exception of ground stations), the development of this capability is only a matter of time. Japanese success has been the result of a number of factors, including:

- a sustained commitment to civilian space development by government and industry

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[91] "Japan Space Effort Moves Into Operational Phase," *A W&ST*, Mar. 8, 1982, p. 107.

[92] Masayoshi Kanabayashi, "Japan Sets Mini-Entry in Space Race, ' *Wall Street Journal*, July 20, 1981.

[93] *Report of the Deliberation Council on Basic Problems in the Space Industry*, MITI, Apr. 20, 1981.

as an integral part of overall plans to keep Japan competitive in advanced technology;

- careful borrowing of technology, mostly from the United States, and assimilation of that technology by Japanese industry;
- close cooperation between government and industry, with general coordination by the Space Advisory Council;
- strong economic performance over the past two decades, together with a rapid maturation of national scientific and industrial skills; and
- willingness by both government and industry to make and adhere to long-range plans.

Competition from the Japanese appears assured during the coming decade and is likely to be particularly strong in Third World countries, where Japan's proven ability to provide high-quality products at low cost may give them an edge over less reliable European and American competitors. In addition, it cannot be ruled out that growing pressure on Japan to increase its military budget and regional defense responsibilities may bring about attempts to make use of its expertise in space technology for military purposes, with the additional boost that such a decision would give to indigenous aerospace and electronics industries. Recently, it was reported that Japan was considering the deployment of a military reconnaissance satellite system, which might be built alone or with U.S. cooperation.[94]

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[94] "Japan Reported Making Plans for Reconnaissance Satellite," *Aerospace Daily*, Jan. 11, 1982, p. 45.

NON-WESTERN SPACE PROGRAMS: SOVIET UNION, PEOPLE'S REPUBLIC OF CHINA, INDIA

Soviet Union

The Soviet Union has for many years maintained a space program approximately equivalent to, and in some areas considerably ahead of, that of the United States both in terms of total resources allocated and the kinds of missions carried out. During the 15 years since it became clear that they would not win the race to land a man on the Moon, the Soviets have made incremental and continuing improvements to their launcher and manned-vehicle systems, as well as developing operational capabilities in domestic and international communications, meteorology, and remote sensing. Over the past several years the Soviets have launched many more satellites than the United States (see table 19).

Table 19.—Total (Civilian and Military) Successful Orbital Launches

	United States	U.S.S.R.
1978	32	88
1979	16	87
1980	13	89

SOURCE: Charles Sheldon 11, "United States and Soviet Progress in Space: Summary Data through 1980 and a Forward Look," Congressional Research Service Report #81-27 S, Jan. 15, 1981, p, 49.

Unfortunately, the extreme secrecy with which the Soviets have surrounded their programs makes it difficult to accurately evaluate their present capabilities and future plans. This secrecy is due to an unwillingness to acknowledge failures and/or technical backwardness for fear of damage to Soviet prestige; to concern that foreign countries might steal or imitate Soviet technology; and to the military nature of most of the Soviet space program and the lack of separation between civilian and military space institutions. It is estimated that 70 percent of Soviet space efforts are purely military, 15 percent are dual military/civilian, and the remaining 15 percent purely civil.[95] All launches are conducted by the Strategic Rocket Forces; the Soviet Air Force operates the Star City cosmonaut training center. Details of the internal organization are not generally available and are subject to controversy. important planning and advisory roles are played by the State Committee on Science and Technology and the Soviet Academy of Sciences.

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[95] *Soviet Military power*, U.S. Department of Defense, September 1981, p. 79.

For these reasons, and because the Soviet program is not oriented towards commercial systems that would be competitive with U.S. or other space technologies, we will not examine the Soviet program in as much detail as the European and Japanese. Brief descriptions of major operational applications systems will be given, with emphasis on potential international implications.

Communications

Soviet satellite communications development initially took a different path than that of the United States. The U.S. satellite communications industry, after initial experiments in the early 1960's with low-orbit satellites and passive reflectors (such as the Echo series), soon turned to active geosynchronous satellites. Because of the relatively well-developed U.S. domestic communication network, satellites were at first aimed primarily at the rapidly expanding overseas market; the United States took the initiative in forming INTELSAT and designating the newly created COMSAT organization to provide the technology and management expertise to make INTELSAT function. In the Soviet Union, however, improving domestic communications, particularly to the less-developed central Asian and Siberian regions, was a high priority, while international traffic was minuscule. The Soviet Molniya 1 system began operations in 1965, using large satellites placed in elliptical 1 2-hour orbits. Such orbits are easier to attain than geosynchronous ones, allowing heavier satellites to be used; they also provide better coverage to areas far north of the Equator, though they require relatively expensive tracking antennas. Similar orbits have been used for the Molniya 2 and 3 series, first launched in 1971 and 1974 respectively. The Molniyas have provided domestic telephone and television services, including color TV transmissions; as more advanced Molniyas have become available, the Molniya 1 series appears to have been reserved for military requirements.[9G]

For a number of reasons the Soviet Union and its allies were reluctant to join INTELSAT when it was founded in 1964. The Soviets objected to U. S./COMSAT management, to the use of U.S. technology, and to the system of weighted voting whereby influence was determined by a country's overall use of the system; the Soviets used only 2 to 3 percent of global international traffic, compared with the United States' s 50 to 60 percent. Instead, in 1968 the Soviet Union and eight other socialist states (Poland, Czechoslovakia, East Germany, Hungary, Rumania, Bulgaria, Mongolia, and Cuba) proposed an alternative system, which in 1971 was formally agreed to and called Intersputnik. Although it is open to any state, few other countries (Syria, Vietnam, and Laos), have joined, for both political and technical reasons. There is relatively little commercial/private traffic between most Intersputnik members and the rest of the world; in addition, since the intersputnik network was initially based on use of the Molniya satellites, it was difficult and expensive for INTELSAT Earth stations, which are designed to work with fixed geosynchronous satellites, to make use of the moving Molniyas. in recent years, however, the Soviet Union has begun to orbit geosynchronous Statsionar satellites which are designed to be more acceptable to global users. In addition, as their international communications needs have grown the Soviet Union, Cuba, and Rumania, (to be followed soon by Poland) have begun to use INTELSAT through Earth stations on their own territories. Increasing de facto integration of global satellite communications appears to be occurring, even in the absence of formal agreements.[97]

The Soviets' first geostationary communications satellite was launched in 1974. A large system of geostationary satellites, called Statsionar, has been established to serve the Soviet Union and East Europe with a number of different kinds of satellites: the Raduga series, six satellites of which had been launched through 1980, for domestic TV and telephone relay; the Ekran series, with six satellites, for domestic television; and the Gorizont series of four satellites for international and domestic television transmission. The current lntersputnik system relies heavily on the Statsionar

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[96] "U.S. and Soviet Progress in Space, " p. 52.

[97] See Nicholas Matte, *Aerospace Law: Telecommunications Satellites,* prepared by the Centre for Research of Air and Space Law, McGill University, for the Social Sciences and Humanities Research Council of Canada, 1980, pp. 118-123.

satellites, and more are expected to be launched in the near future; the Soviets are currently several years behind in their projections for overall system deployment.[98]

The Soviets have also announced plans for several new global communications systems designed to compete with western ones. The Loutch series of eight satellites is intended to provide services comparable to INTELSAT, using 14/11 GHz frequencies; the Volna mobile communications system of seven satellites plans to offer services to ships and planes similar to those of Marisat and Aerosat. To date none of these planned satellites have been flown.[99]

It would appear that the Soviets, after many years of concentrating on domestic and regional capabilities, are hoping to compete on a more global scale. Such an effort stems from: 1) increasing confidence in their technology, based in part on military experience gained in communicating with a rapidly expanding number of naval vessals and foreign bases and 2) an increase in international civilian communications with Western and third world states, due largely to expanded trade relations. Not enough is known about the critical factors to estimate whether Soviet competition will be effective: these include the system's technical characteristics and reliability, its compatibility with other global and regional systems, how the prices charged for services compare with Intelsat and other alternatives, the institutional characteristics of any potential user group, and political considerations.

Remote Sensing

The Soviets have no specifically designated civilian land remote-sensing system. Large numbers of short-term film-return Cosmos missions have been flown for military purposes, and some of these have undoubtedly provided civilian data. Ocean surveillance for the military has been carried out using nuclear-powered active radar satellites; two specialized nonnuclear oceanographic satellites are reported to be in operation. The latest such satellite, Cosmos 1151, was launched in January 1980.[100]

Perhaps the most ambitious civilian-oriented remote-sensing work has been done on manned missions, particularly the Salyut 6. Some 50,000 photographs have been taken using a large MKF-6m multispectral camera built by Carl Zeiss Jena in East Germany, and some of the data obtained has been shared with allied and developing countries, such as Cuba, Vietnam, Morocco, and Angola.[101]

The Soviets have been distributing weather photos from their Meteor series meteorological satellites since 1966; their first retrograde Sun-synchronous launch, capable of providing daily coverage of a particular area at the same time of day, was made in 1977. Meteor satellites have carried a variety of experimental sensors including, recently, advanced Earth resources instrumentation.[102] In July 1980, the Soviet Union launched a prototype remote-sensing satellite with three experimental multispectral sensors providing ground resolution up to 30 m, with data to be relayed to the ground via radio. It is planned to extend this to a full-scale operational system with 50-m visible-band resolution.[103]

In the U. N., the Soviets have proposed since 1979 that distribution of "local," i.e., 50 m or less, remote-sensing data be subject to the prior consent of the state being viewed; this does not affect Landsat 3 MSS imagery but would apply to TM data from Landsat D, as well as France's proposed SPOT system. The Soviet proposal is designed to restrict the usefulness of U.S. and other Western remote-sensing systems, as well as to limit the dissemination of potentially damaging information about the Soviet Union and its allies (e.g., agricultural data that might give foreign

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[98] "Soviets Continue Aggressive Space Drive," *AW&ST,* Mar. 9, 1981.

[99] "Soviets Increasing Space Activities," *AW&ST,* Mar. 3, 1980, p. 83.

[100] "Review of National and Co-Operative Space Activities for the Calendar Year 1980," UNCOPUOS, A/AC'. 105/286/Add. 3, May 1, 1981, p. 11.

[101] "The Salyut 6 Mission," *Interavia,* November 1978, p. 1,084; "Relevance of Space Activities to Monitoring of Earth Resources and the Environment," prepared for 2d U.N. Conference on the Exploration and Peaceful Uses of Outer Space, A/Conf. 101/BP/3, Apr. 28, 1981, p. 8.

[102] Craig Covault, "Soviets Initiating Program on Modular Space Station," *AW&ST,* July 21, 1981; "Review of Space Activities," p. 10.

[103] "National Paper: USSR," prepared for 2d U.N. Conference on the Exploration and Peaceful Uses of Outer Space, A/Conf. 101/NP/30, Sept. 2, 1981, p. 19.

firms a better bargaining position with Soviet purchasers). The United States opposes such a restriction. [104]

There are presently no known Soviet plans to distribute remote-sensing information outside the U. S. S. R.; entry of the Soviets into the global market, even on a selective basis, could have a significant effect on future Western commercial systems. The Soviets would be likely to sell/ distribute data for political purposes, which could mean undercutting global prices while criticizing Western systems (especially those run as private commercial enterprises) for being too expensive for and/or violating the sovereignty of developing countries.

Materials Processing

Processing experiments have had a high priority on recent Soviet space flights, especially aboard the Salyut 6 orbiting laboratory.[105]o~ Two separate furnaces, the Splav-01 and Kristall, have been used to conduct experiments on semiconductors, crystal growth, alloys, glasses and metal oxides; samples have been taken to the ground for detailed analysis. Approximately 300 to 350 Soviet scientists are reported to be actively engaged in materials research related to space processing.[106]

As usual, details of Soviet results are not publicly available; activities appear to be at the basic science level, and can be expected to continue with future Soviet manned flights. Soviet spokesmen are characteristically optimistic about space manufacturing; a typical observation is cosmonaut Konstantin Feoktistov's recent claim that there will eventually be "whole plants for manufacturing products in zero-g. ''107

Launch Vehicles and Manned Operations

The Soviets have developed a number of expendable launch vehicles; the most commonly used is the Sapwood (A) launcher, a derivative of the original ICBM design dating back to the mid-l950s, which in present modified versions can launch Soyuz manned vehicles up to 6,575 kg. The larger Proton (D) launcher can carry 20,000 kg to LEO and has been used to launch the Salyut space stations; it is not considered reliable enough for manned launches. [108]

The Soviets have so far failed to produce advanced ELVS comparable to the U.S. Saturn V, which could lift 136,000 kg to LEO, or a reusable vehicle such as the space shuttle. This has been due in part to their inability to develop high-energy liquid hydrogen/liquid oxygen propulsion systems, without which launching heavy payloads requires a very large number of stages and strap-ens. The Soviets apparently attempted to launch a Saturn-size vehicle on at least three occasions from 1969 to 1972 as part of their manned lunar program, but were unsuccessful. There are currently unconfirmed reports that the Soviets are once again seeking to launch a very large ELV, as well as to develop a reusable vehicle somewhat smaller than the shuttle. Both advances would be useful in implementing the Soviet aim of developing large permanently manned orbiting Space stations.[109]

In recent years the main emphasis of the Soviet space program has been on developing and using the Salyut series of manned orbiting laboratories. The first Salyut prototype was launched in 1971; since then five more have been orbited, four successfully. Several (Salyuts 2, 3, and 5) have apparently been military in nature, mainly for high-resolution reconnaissance; Salyuts 4 and 6 have been civilian.[110] Salyut 6, still in orbit, has been by far the most successful. Weighing 42,000 lb, it has been visited by 13 separate 2- and 3-man Soyuz crews, including a large number of non-Soviet nationals. The Salyut 6 has also rendezvoused with unmanned Progress tankers, which can dock automatically to resupply the men aboard. This has enabled the Soviets to conduct long-duration missions, including the world

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[104] James Kay, "The Legal Implications of Remote Sensing by Satellite, " prepared by Centre for Research of Air and Space Law, McGill University, for the Social Sciences and Humanities Research Council of Canada, March 1981, p. 73.

[105] B. Belitsky, "Soviet Manned Space Flight 20 Years on, " *Spaceflight,* vol. 23, No. 5, May 1981, pp. 154-155.

[106] *U.S. Must Spend More to Maintain Lead in Space Technology,* GAO Report FGMSD-80- 32, Washington, D. C., Jan. 31, 1980, p. 8.

[107] 'Soviets Show Assembly of Space Station Units," *AW&ST,* June 29, 1981, p. 21.

[108] '' U.S. and Soviet Progress in Space, " pp. 23-25.

[109] Craig Covau It, "Soviets Developing 12-Man Space Station, " *AW&ST,* June 16, 1980, pp. 26-29.

[110] Nicholas Johnson, "The Military and Civilian Salyut Space Programmes,'' *Spaceflight,* August-September 1979, p. 364.

record of 185 days in orbit recorded by Valery Ryumin and L. Popov in 1980. Numerous experiments and studies have been conducted to test the spacecraft themselves as well as the effects of weightlessness on human beings, other plant and animal life, and inorganic materials. Salyut cosmonauts have succeeded in working outside the spacecraft to make repairs and to deploy instruments, such as a 33-ft radio telescope.[111]

In June 1981 Salyut 6 was visited by a new large (30,000 lb) unmanned craft, designated Cosmos 1267, which is twice as large as the Progress/Soyuz vehicles. The automatic docking performed by the two vehicles appears to point the way to the construction of large modular space stations with many times the interior room of the current Salyuts.[112] The Soviets have consistently pointed to the establishment of such stations as the central goal of their space program and as a necessary step in conducting further space activities, including eventual manned missions to the Moon and planets. In March 1982 the Soviets launched a new station, Salyut 7.

Cooperation and Competition With Other Countries

The bulk of Soviet joint and cooperative projects have been conducted with allied socialist states. In 1967, the Interkosmos program was founded to coordinate activities between the Soviet Union, its East European allies, and other communist states such as Mongolia, Cuba, and more recently Vietnam. A number of scientific satellites have been flown using instruments, designed by member-states, under the overall direction of the Soviet Union. Instruments and experiments, such as East Germany's multispectral camera, have also flown on the Salyut series; many of these were associated with the flight of guest cosmonauts from participating states. To date, cosmonauts from Czechoslovakia, Poland, East Germany, Bulgaria, Hungary, Rumania, Mongolia, Vietnam, and Cuba have been trained in the Soviet Union and spent time on board Salyut 6. These missions have helped give the Soviet program a politically valuable international image; further such flights, including cosmonauts from non-Interkosmos nations, such as France and possibly India, are being planned.

Soviet-U.S. space relations have had several ups and downs, generally mirroring the overall political climate. The period of initial rivalry from 1957 through the Apollo program was characterized by extreme competition and mutual claims of superiority, often made difficult to verify on account of the secrecy with which the Soviet program was conducted. The Apollo success was typically downplayed by the Soviets, who stressed the superiority of their unmanned Lunokhod lunar explorers and the "wastefulness" of the U.S. manned program, implying that the Soviets had never intended to send men to the Moon.[113] However, even during this period the two countries found it necessary to cooperate in establishing legal and regulatory principles for space activities. In the early 1970's, as the end of the Vietnam War allowed closer relations to develop and "detente" became the official policy of both the U.S. and Soviet leadership, planning began for a cooperative manned mission, the Apollo-Soyuz test project (ASTP). In May 1972, a comprehensive agreement was signed in Moscow as part of the Nixon-Brezhnev Summit. The agreement covered a variety of mutual scientific and technical exchanges in addition to ASTP.[11A] The ostensible rationale for the mission was to develop a joint docking system so that, in case of emergencies, spacecraft from either of the two states could rendezvous with those of the other. However, the joining together of the two spacecraft became symbolic of the then current "thaw" in relations, and was seen by proponents as leading towards extended cooperation in future space (and non-space) activities. Critics saw it as an expensive political stunt which was likely to give the Soviet Union greater benefits than the United States, in-

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[111] Craig Covault, "Radio Telescope Erected on Salyut 6," *AW&ST,* Aug. 13, 1979, pp. 54-55.

[112] James Oberg, "The Soviet Aim: a permanent base in space," New *Scientist,* Oct. 1, 1981.

[113] James Oberg, "The Moon Race Cover-Up," *Reason,* August 1979, pp. 34-37.

[114] *Soviet Space Programs 1971-75,* Staff Report for Senate committee on Aeronautical and Space Sciences, Aug. 30, 1976, vol. II, p. 105.

sofar as the perceived technical parity between the two systems would tend to elevate the public image of the Soviet Union as no longer "behind" in space technology. For various reasons the July 1975 rendezvous of Apollo and Soyuz 19, though spectacular, did not lead to further major cooperative activities; this was largely due to the different directions the two programs took in the second half of the 1970's, as well as to increasing political tensions. Some of the cooperative projects, such as U.S. biological experiments carried on Cosmos flights in 1975, 1977, and 1979, and exchanges of data from each country's planetary missions have continued, but there are no plans for a resumption of major scientific or applications exchanges. In 1977, a second agreement was concluded between NASA and the Soviet Academy of Science outlining cooperation in the development of a compatible sea search-and-rescue system, along with further cooperation in manned space flight. Although preliminary meetings were held, the studies were never completed; the Soviets blame the United States for not fulfilling this latter part of the agreement.[115]

The Soviets and United States are at odds in the U.N. over a variety of space issues, such as the proper restrictions to be placed on DBS and land remote-sensing systems. More importantly, the growing military importance of space technologies for surveillance, communications and navigation has made each side more concerned about the other's capabilities, and less prone to cooperate directly with the other. The Soviets have consistently criticized the shuttle as a space weapon while carrying out active tests of an antisatellite system.

Despite extensive publicity for space exploits, the Soviets have made only minor attempts to actively disseminate either space technology or its benefits to third-world countries, as the United States has done through NASA cooperative agreements and the Agency for International Development (Al D). Outside of allied socialist countries and the United States, significant cooperation has been pursued with only three countries–France, India, and to a lesser extent, Sweden. India's first satellite, called Aryabhata, was launched by the Soviet Union in 1975; in 1979 an Earth-observation satellite, Bhaskara-1, was launched, and Bhaskara-11 was orbited in November 1981. Cooperation with France, outlined earlier in the section on the French space program, has been pursued in materials processing, space biology, and manned flight.

The Soviet space effort is large and varied and the above has done no more than sketch their major programs. As opposed to the U.S. space effort, it seems fair to say that over the past decade, the Soviet program has been characterized by steady growth and extension of their capabilities. Despite slowness in meeting certain goals for communications services, ambitious programs in communications, remote sensing, and especially the construction and operation of orbital stations have been successfully implemented. However, it is still an open question whether increased Soviet capabilities, and increased confidence in their technology, will induce the Soviets to offer applications services to a broader range of global customers. Space technology is one of the few areas in which the Soviets could be competitive with the West, and the political and economic gains of supplying hardware and services would be attractive. However, Soviet inexperience at operating in a competitive business environment may prove, in this as in other fields, to be a major barrier. In addition, the marketing of services—as opposed to simple hardware—which require close cooperation between supplier and customer would run counter to the Soviets' long-cherished practice of maintaining maximum secrecy about their technical capabilities, especially in areas where the military is so closely involved. For these reasons it is likely that the Soviets will choose to compete selectively, for discrete political aims, rather than enter into general competition for satellite communications, remote-sensing, or launch service markets.

People's Republic of China (PRC)

The PRC'S launch technology has been derived from the Soviet Union, primarily the SS-4 (Sandal) medium-range liquid-fueled missile, designs for which were given to the Chinese in the late

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'l'" National Paper: U. S. S. R," p. 110.

1950's before relations between the two countries broke down. The central impetus for the development of further launchers and satellites has been to meet security needs: to carry nuclear warheads to the population centers of the Soviet Union, and to provide military reconnaissance and communications.

The first Chinese satellite, the 173 kg China 1, was launched in April 1970 by a CSL-I (Long March 1) launcher. Since then 10 more satellites have been launched (including a recent three-in-one payload of scientific satellites). Little is known about their characteristics, though some were clearly for military reconnaissance and communications. Starting with China 3 in 1975, launches were made with the FB-1 (Storm) vehicle, a version of their CSS-X-4 ICBM, approximately equivalent in size to the U.S. Atlas. The FB-1 can launch a satellite of up to 2 tons into LEO.[116]

The Chinese are known to be working on a new launcher, the Long March 3, which would use the two stages of the FB-1 plus a liquid oxygen/liquid hydrogen upper stage. If successful, this would make them third in the world, after the United States and ESA (perhaps fourth if the Japanese succeed first), to use high-energy cryogenic fuels. The Chinese recently announced that the Long March 3 would be launched in 1983 or 1984 and would probably carry China's first experimental geosynchronous communications satellite.[117]

To date the PRC has no operational communications, meteorological or remote-sensing satellites, but plans are under way to develop all three technologies. Since 1972 and the United States-Chinese rapprochement, China has received significant data and know-how from the United States. INTELSAT-compatible receiving stations have been bought and established near Peking and Shanghai. An experimental COMSAT, the STW-2, is scheduled for a 1983 or 1984 launch over the Pacific, and indigenous Earth stations and transmitters have been built.118 Transmission tests using the France-German Symphonic have included video teleconferencing and high-resolution facsimile transmission. According to terms of the "1979 Understanding on Cooperation in Space Technology" (part of the *United States-China Agreement on Cooperation in Science and Technology),* the Chinese Communications Satellite Corporation indicated a desire to purchase a U.S. communications satellite (to be launched by NASA) including ground equipment, but plans have been postponed indefinitely due to financial constraints. Discussions also took place in 1979 and 1980 with non-U.S. partners such as West Germany's Messerschmitt-Bolkow-Blohm.119

PRC currently receives meteorological data from the U.S. Tires-N and NOAA- 6, and the Japanese GMS-1 satellites through indigenous receiving stations. The Central Meteorological Bureau had planned to launch a Sun-synchronous weather satellite in 1982, and a complementary geosynchronous satellite in 1985. The 1982 satellite's radiometer was to have a 4-km resolution (compared with the U.S. ITOS' resolution of 1 km). Due to cutbacks in Chinese R&D expenditures, the status of these plans is uncertain.

In remote sensing, the Chinese plan to use Landsat and SPOT data extensively before developing their own system; the "1979 Understanding" indicates China's intention to purchase a Landsat ground station from U.S. industry, and procurement activities are continuing. The Shanghai Institute of Technical Physics is reported to be working on various sensors including a multispectral scanner.[120] In January 1980, NASA and the Chinese Academy of Sciences concluded a memorandum of understanding giving the PRC direct access to Landsat data.

There have been several reports that the Chinese are planning seriously for eventual manned flights and have begun to train astronauts for future missions.[121] However, China's recent reassessment of internal economic and scientific

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[116] Edelson Haas et al., "Eyewitness Report on Chinese Satellite Work," *Aeronautics and Astronautics,* February 1980, p. 44.

[117] China Launches Three-in-One Satellite Payload, " *Aerospace Daily,* Sept. 22, 1981, pp. 113-114.

[118] Eyewitness Report," p. 41.

[119] MBB, Chinese Discuss TV Satellite," *AW&ST,* Mar. 31, 1980, p. 63.

[120] Eyewitness Report, " p. 43.

[121] See David Ritchie, "Dragon in the Sky: China's Space Program, " *Technology Review,* October 1981, pp. 53-54.

priorities has apparently resulted in a postponement of plans for manned flights in the 1980's.[122]

Until recently China's space capabilities were barely known. Since the death of Mao and the determination of China's new leadership to modernize the country by increasing foreign trade and educational/scientific exchanges with the West, a number of official and unofficial foreign delegations have been allowed to visit Chinese space facilities. In turn, large numbers of Chinese have visited U. S., European, and Japanese facilities, and many Chinese students are now attending Western engineering and graduate programs in the sciences. Up to now, except for initial aid from the Soviet Union, Chinese efforts have been almost exclusively home-grown. Military requirements have been paramount, but there has also been recognition that satellites could play a large role in upgrading China's internal communications and television networks, in locating and managing mineral and energy resources, and in agricultural planning. Given the previous lack of access to outside technology, Chinese capabilities are impressive, and are likely to expand rapidly in the near future if outside contacts increase and internal constraints are relaxed. The major difficulties are likely to be a shortage of trained scientists and technicians, due to the educational disruptions of the cultural revolution; lack of capital and other strains caused by ambitious plans for rapid modernization of the entire economy; and lack of foreign exchange for the purchase of outside technology. Though Mao's absolute insistence on domestic self-reliance has been relaxed, China is likely to be interested in such purchases primarily as a way of gaining access to technology to be copied or otherwise appropriated; hence, although China will not in the near future be competing with foreign firms or governments for commercial contracts, it is also not likely to be a major buyer of space systems.

India

India has had a formal space program since the formation of the Indian National Committee for Space Research (INCOSPAR) in 1962. In 1969, INCOSPAR was absorbed by the Indian Space Research Organization (ISRO), which in 1972 became the central body of the newly created Department of Space.

Unlike China's, India's space activities have not been motivated by military concerns (the military has a separate interest in antitank and antiaircraft missiles). Although India is an underdeveloped country, it has, because of its size and longstanding contacts with the West, a considerable pool of scientific and administrative talent. The space program is designed to use these resources to encourage development, to foster technical and scientific leadership, and to serve as an example (in accord with India's overall position of neutrality between East and West and a leader of the nonaligned movement) of indigenous Third World achievements in areas usually considered the preserve of advanced developed countries. Hence there is an emphasis on developing a comprehensive space capability, and especially systems for rural communications, land management, and weather forecasting. Foreign assistance has been welcomed from a number of countries, largely for demonstration projects and joint programs, with the intention of building on the experience gained to provide similar services with indigenous resources. Through 1979, India's total investment had amounted to some $230 million, with somewhat higher expenditures anticipated in fulfilling the latest 10-year plan.[123]

India has built and launched a large number of Rohini sounding rockets, in addition to providing a launch platform for U.S. and Soviet sounding rocket experiments.[124] In July 1980, India successfully tested its four-stage solid fuel SLV-3 launcher, orbiting the 76-lb Rohini I research satellite; in 1981, it launched a second Rohini, which failed to achieve orbit. Plans are under way to produce an augmented SLV, using strap-on boosters, that could place 330 lb into LEO, as well as to develop a new launcher capable of orbiting a 600-lb remote-sensing satellite by the mid-1980 's. Though strongly denied by India, there are fears, especially in Pakistan, that

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[122] See "Chinese Astronauts Train in Simulators," *AW&ST*, Jan. 26, 1981, p. 63.

[123] H. P. Mama, "India's Space Program: Across the Board on a Shoe String," *Interavia*, January 1980, p. 60.

[124] "World-Wide Space Activities," p. 119.

India’s launchers may be used as, or be the precursor to, a delivery system for nuclear weapons.

India’s first satellite, the Aryabhata, was launched by the Soviet Union in 1975; it was largely Indian-built and designed, with Soviet assistance. In 1979, the Soviets launched India’s Bhaskara I remote-sensing satellite, which suffered a partial power failure. The Bhaskara 11, containing two television cameras and three microwave radiometers~, was launched in November 1981, and has provided television pictures of the sub-continent.

Another cooperative venture was the June 1981 launch of an experimental communications satellite, the Apple (Ariane Passenger Payload Experiment), on ESA’S third Ariane test vehicle. The satellite suffered a partial failure of its solar-powered electrical system but has continued to function with reduced capability.[125]

India plans to establish an operational communications system, called Insat, using two satellites purchased from Ford Aerospace and launched by the U.S. Insat-1 was launched in April 1982, and will relay messages and data between approximately 32 proposed ground stations, as well as provide direct television service to rural communities via several thousand inexpensive antennas.[126] Insat will also carry a VHRR to provide’ meteorological information. Eventually, ISRO plans to produce its own follow-on system, building on experience gained with Apple and Insat.

India’s commitment to Insat has been due largely to the positive experience gained with two major cooperative communications satellite projects, one with the United States and the other with Europe. The Satellite Instructional Television Experiment (SITE), which lasted for 1 year from August 1, 1975, to July 31, 1976, was a joint program with NASA using the ATS-6 large communications satellite to broadcast educational television programs to 5,000 Indian villages. India was responsible for maintenance of the ground equipment and for developing the programs; the overall reaction proved highly favorable and enabled the Government to disseminate important information on health care, agricultural techniques, and birth control to previously inaccessible areas. Additional experiments, including teleconferencing and emergency communications, were conducted through the Symphonic Telecommunications Experimental Project (STEP) from July 1977 to mid-l 979, using the French-German experimental Symphonic communications satellite.

In remote sensing, India is one of 11 foreign countries to have a Landsat receiving station. Located at Hyderabad, it is operated by the National Remote Sensing Agency. Current plans call for a remote-sensing satellite to be developed and launched sometime in the mid-1980’s, building on experience with the Bhaskara series.

India has amassed a large amount of experience in designing, building and operating a variety of applications systems. The commitment to achieving an independent capability to use space technology is longstanding and based on the beneficial results of past usage. Though direct competition with Western or Japanese systems is not likely in the near future, Indian experience in adapting space capabilities to developing country needs could eventually give them an advantage in providing services and/or hardware to Third World countries.

OTHER SPACE PROGRAMS

Canada

Canada’s space activities are coordinated by the Interdepartmental Committee on Space (ICS), with overall responsibility in the Minister of State for Science and Technology. Canada has participated in a large number of joint scientific projects with the United States, including the Canadian-built Alouette and ISIS ionospheric research satellites, launched by NASA. The Department of Communications cooperated with NASA and ESA in operating the experimental

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[125] “Apple Satellite Operational Despite Panel Failure,” *AW&ST,* Sept. 14, 1981, p. 19.

[126] Benjamin Elson, “U.S. to Launch Insat Satellite for India,” *AW&ST,* Apr. 5, 1982, pp. 56-63.

Communications Technology Satellite (CTS) from 1976 to 1979, which pioneered operational use of the 14/12 GHz band. Spurred by the difficulties of communicating with remote regions in the North, Canada in 1972 became the first Western country to initiate operational domestic communications via satellite; the Anik A series of three comsats were built by Hughes and launched by the United States. In 1978, Telesat Canada began using RCA's Anik B for voice, data, and television transmissions. Three Hughes-built Anik C spacecraft are scheduled for launch beginning in November 1981.

Canada is also engaged in a major bilateral program with NASA to develop a remote manipulator arm for the U.S. space shuttle. Spar Aerospace Ltd. is developer for the $100 million project. The first arm flew on the second shuttle flight in November 1981. As with ESA'S Spacelab, Canada has agreed to pay for development of the arm and the first prototype, in return for a NASA commitment to purchase additional arms from Spar.[127]

Brazil

Brazil has had an active interest in space activities since 1961, especially satellite communications and remote sensing to manage its far-flung territories and to assist in the development of the Amazon Basin. The Centro Tecnico Aerospecial (CTA) has been responsible for developing the Sonda series of sounding rockets, which are launched from Brazil's launch facility at Natal in the northeast part of the country. The United States, Germany, and other countries have also used Brazil's facilities; a new launch center is now being prepared closer to the Equator.

In 1975, Brazil and NASA conducted the SACI (Advanced Satellite for Interdisciplinary Communications) experiment, using NASA's ATS-6 satellite to transmit television programs to remote primary schools. Brazil currently leases four transponders from INTELSAT for domestic use (with plans to increase this to 81/2 transponders by 1986), and plans to purchase its own comsat (with provision for technology transfer), to be launched in 1985.

Brazil is, after the United States, the largest user of Landsat data, and has operated a Landsat ground station since 1973, along with processing facilities. There are currently plans to design and build four remote-sensing and meteorological satellites, with the first one to be launched in 1988.[128]

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[127] Craig Covault, "Remote Arm Aids Shuttle Capability," *A W&ST,* Sept. 7, 1981, pp. 57-58.

[128] Jim Brooke, "Brazil's Space Program Prepared to Launch 4 Satellites by 1993, " *Washington Post, Nov. 26, 1981,* p. A22.

DOMESTIC/REGIONAL COMMUNICATIONS SYSTEMS

In addition to the national programs outlined previously, there are a number of regional satellite communications systems that are either already in operation or in various stages of planning,

Indonesia has had the two Hughes-built satellites of its Palapa A system operating since 1976 to link its widespread island area. Spare channels have been leased by other countries in the region. The first Palapa B satellite is scheduled for launch in 1983 and will be used by the Philippines, Thailand, and Malaysia. The Arabsat system, with 21 Middle Eastern countries as participants, is scheduled for a first flight in December 1983. France's Aerospatiale is the prime contractor, with Ford Aerospace the major U.S. participate. Australia's Australsat is planned for the mid-1 980s. Regional systems have been discussed for Southern Africa and South America, particularly the Andean region, prompted by Colombia's well-developed plans for its Satcol telephone and TV system.[129] Currently, a large number of countries lease spare transponders from INTELSAT satellites and purchase ground stations for domestic use. This activity, along with the national and regional systems mentioned, in-

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[129] See Theo Pirard, "Space Systems Operated and Prepared by Developing Countries, " *Spaceflight,* May 1981, pp. 137-139.

dicates the scale of global interest in satellite services. This is important, first because of the implications for the current international communications system, i.e., for INTELSAT; and also because, given the stakes, competition for sales of satellites, ground equipment, and launch services between U. S., European, and Japanese firms” is likely to be fierce. The proliferation of satellites for local and regional use threatens to take business away from INTELSAT, damaging its financial viability. As communications needs become greater and more specialized, and as it becomes progesssively more difficult to allocate scarce orbital slots and frequencies, many countries are determined to have their own system, or a share of a local system, regardless of whether such a move is warranted by local demand or by financial considerations. Such decisions are supported by increasingly competitive private and national suppliers of telecommunications equipment, who encourage the purchase of specialized services. The long-term effects on INTELSAT are unclear but may lead to higher prices or reduced service, which would be especially harmful to those countries that are too small or poor to purchase their own system.[130] A possible solution would be an expansion of the INTELSAT system to provide local and regional services. This would require a satellite-ground-station system designed to operate in low-density rural areas, perhaps including direct-broadcast capabilities.

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[130] See John McLucas, **“Global Cooperation in Satellite Communications in a Decade of Policy Divergence, ” paper presented at International Aerospace Symposium, Paris, France, June 2, 1981.**

REMOTE SENSING IN DEVELOPING COUNTRIES

In the field of land remote sensing, the analogue to INTELSAT has been the U.S. Landsat system, which has provided black-and-white and multispectral photographs on a global basis for the cost of reproduction. U.S. policy was established in 1969, when President Nixon stated at the 24th U.N. General Assembly that “this program will be dedicated to produce information not only for the United States but also for the world community. ” Foreign nations and agencies can either purchase data from the EROS Data Center, or receive it directly by establishing their own receiving station, which can (with the current Landsat satellites) provide images over a 2,700-km radius (see map). Especially in developing countries where maps are often incomplete and outdated, and information about land use, forest cover, drainage patterns, mineral deposits and the like is difficult and expensive to obtain, satellite imagery has been used extensively to aid in economic development.[131] Over the years, substantial assistance has been provided, largely by the U.S. Agency for International Development and also by other developed countries and international organizations, to enable various countries to use Landsat. Effective use requires skilled technicians and equipment to process the data, as well as integration of satellite information with many other information resources. Multilaterally funded training centers to encourage these capabilities are being established in Upper Volta, Kenya, and Thailand.

As was discussed above, other global land remote-sensing systems besides Landsat are planned for the mid-1980’s. Though such competition may eventually improve the quality of services available, much depends on whether the competition is political or commercial in nature. Private-sector operation of Landsat, which could put remote sensing on a more commercial basis, is of concern to many developing countries who see such a move leading to higher prices as well as possible violations of their sovereignty by private companies outside effective government control. On the other hand, a “price war” between, say, politically motivated Landsat, SPOT, MOS, and possible Soviet systems might prove beneficial to users but might also undermine the willingness of the sponsoring governments to continue their operation. The multiplication of

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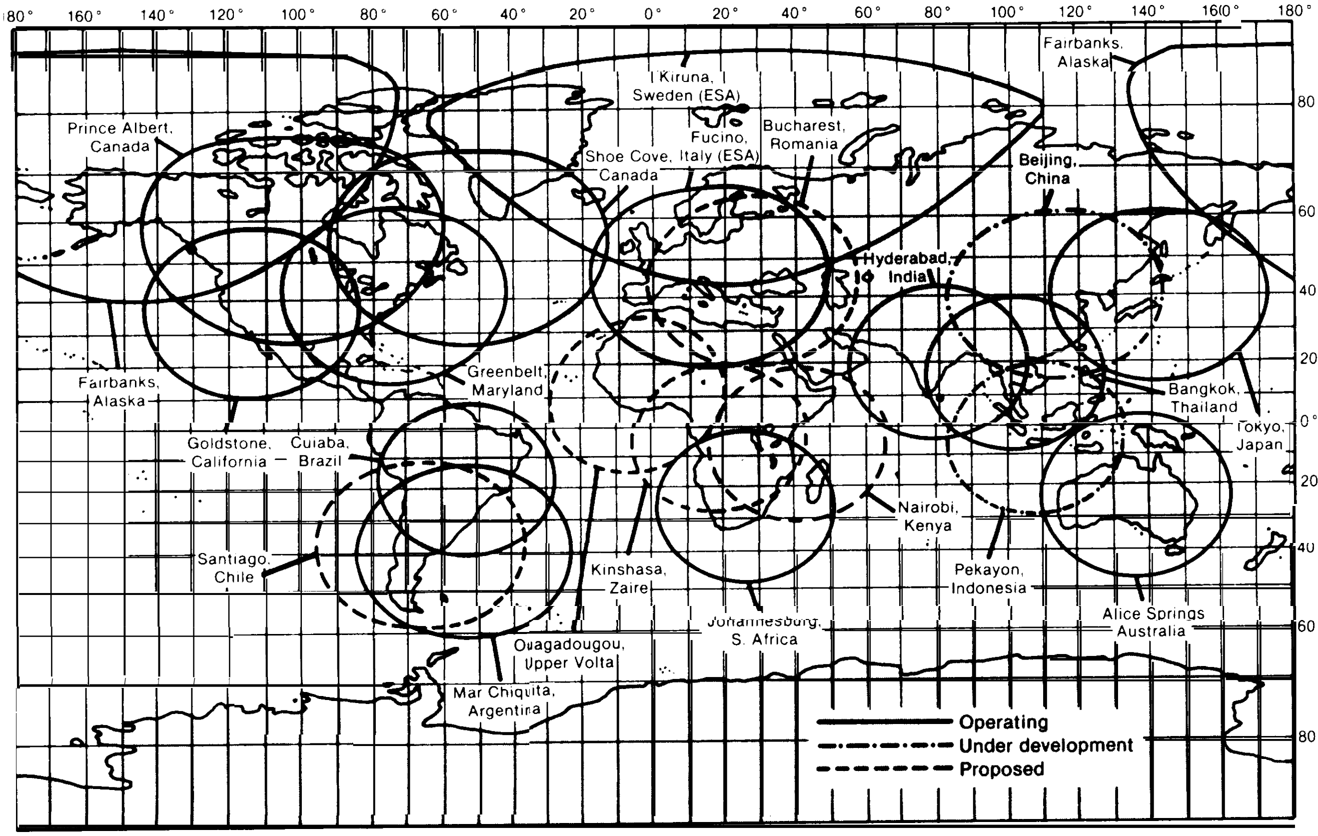
[131] For an outline **of some of these uses, see “Relevance of Space Activities to Monitoring of Earth Resources and the Environment, ” background paper for second U.N. Conference on the Exploration and Peaceful Uses of Outer Space, A/Conf. 101/BP/3, Apr. 28, 1981.**

Figure 14.—Current and Probable Landsat Ground Stations



NOTE: Coverage circles based on Landsat-3 reception (altitude: 917 km)

SOURCE" National Aeronautics and Space Administration

remote-sensing systems could prove wasteful and make the integration of global and regional data, necessary for many applications purposes, more difficult. At the same time, many countries are concerned about the dangers of allowing information about their resources to be appropriated by a multiplicity of nationally owned satellites or, worse yet, sold to the highest bidder. For these reasons, some sort of international civilian remote-sensing structure has occasionally been proposed;[132] for a detailed discussion see the Globesat section in chapter 10 of this report. At the present, however, no country or organization has taken the lead in proposing such a system or in establishing the institutional and financial framework that would be needed. Discussion of ways to better use and integrate remote-sensing data, along with other issues of concern to developing countries, will be on the agenda at the upcoming second U.N. Conference on the Peaceful Uses of Outer Space (UNISPACE 1982) to be held at Vienna this coming August. A number of proposals to establish new U.N. bodies dealing with space activities and/or to expand the scope of existing ones will be proposed at the Conference and passed on by the General Assembly in the fall of 1982.

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[132] See Robert White, "Land, Sea and Air: The Global Implications of the View From Space," paper presented at Conference on Global Implications of Space Activities, Aspen, Colo., Aug. 30-Sept. 4, 1981, pp. 14-22.

Chapter 8

COMMERCIALIZATION OF SPACE TECHNOLOGY

Contents

Chapter 8

COMMERCIALIZATION OF SPACE TECHNOLOGY

INTRODUCTION

A commercial activity is generally understood to be one undertaken for profit in the public marketplace; "commercialization" then implies the transfer of technology from a research and development (R&D) and/or federally supported operations stage to a for-profit stage, usually under private sector ownership and control. It is difficult to give a precise definition for commercialization because the term assumes a variety of specific meanings depending on the context in which it is used. For example, aerospace companies earn a profit on the aircraft they manufacture for the military, but military aircraft are generally not considered to be commercial products, except insofar as they are sold to other countries. Civilian aircraft, on the other hand, are considered thoroughly commercial, in that they are designed, developed, and sold to make a profit in a competitive marketplace. Nonetheless, such aircraft depend partly on technology developed by the Federal Government, either for military use, or in a Government research program.

Though the desired result of all efforts toward commercialization may be similar (i. e., to earn a profit in a competitive environment), the processes necessary to achieve this result and the sources of the technologies involved are often quite different. Such differences become significant in a context such as the U.S. space program, in which commercialization of space technology is encouraged as a matter of policy. The purposes of this chapter will be to: 1) identify some of the problems involved in trying to commercialize specific space technologies; 2) examine private sector attitudes towards commercialization; and 3) describe some of the current Government programs implemented to encourage commercialization.

This chapter begins with a discussion of the special factors that space introduces to the process of industrial innovation. New product, process, and service innovations are analyzed along with the barriers and inducements to their commercialization. The remainder of this chapter discusses several of the current space-related, profitmaking activities and indicates areas in which the private sector may invest in the future.

PROCESS OF INDUSTRIAL INNOVATION IN SPACE

Overview

In most areas of business opportunity, Federal R&D funds support or supplement larger private R&D investment. Public funds are generally thought to be justified for basic research into high-risk pursuits with long payback times, or for technologies having obvious social benefits. With respect to space, and with the notable exception of some communications applications, the private sector has invested relatively little in R&D exploring new business possibilities. This puts the Federal Government in the position of pushing technological opportunities in an area without substantial business interest beyond the aerospace community or an established or integrated market. The purpose of this section will be to explore the Government's recent emphasis on commercializing space technology and the reasons behind the reluctance of the private sector to invest capital in space research.

Although the basic characteristics of the innovative process (see app. H) can be applied to any industry, innovation in space technology raises several unique problems. Among the special characteristics of space-based innovation, the following stand out:

- ***Entry costs are extremely high. No*** form of ground-based research, development, and demonstration can do away with the requirement for testing of systems in space before a new business using space-based technology can apply it commercially. Access to orbit is very expensive, and will continue to be expensive even in the shuttle era, particularly if compared with the costs required to develop and demonstrate the commercial viability of most Earth-based innovations. Even with the less stringent design requirements of the shuttle payload bay, space systems are more expensive to design than their Earth-bound equivalents. The cost of using the shuttle as a laboratory to verify or develop potential innovations may discourage many potential developers. This additional expenditure, incurred well before commercial feasibility has been established, is a radical departure from normal product development on Earth.

- ***Government controls the means ot access to space.*** Until some entrepreneur is capable of operating a reliable space launch system, access to space will be through launchers developed and operated by the Government, In few other business sectors is an essential element of the innovative process totally under Government control. Access to launches, launch assurances,. availability of support facilities, and the cost of space transportation may all be influenced by nonbusiness considerations such as changes in an administration's space policy, national security constraints, or fluctuations in congressional and public support. If the necessary space facilities are not available when needed, the resulting costly delays could be fatal to a new commercial program.
- ***The markets for space industrialization are undeveloped.*** Unlike innovations that emerge from an existing or clearly possible market opportunity, some space-based businesses will be based on totally new capabilities that will have to create new markets. Communications satellites, the often cited example of successfully commercialized space technology, were a more efficient substitute for existing means of long-distance communication. This interchangeability of technologies is not characteristic of many of the other space-based business opportunities which have been identified to date.
- ***Public interests dominate space activities.*** There are few areas of space applications in which one or more of the following public concerns—national security, international economic competition, return to the public from the investment of Government funds, improving the quality of public services provided by Government—are not influential. As a result, it is difficult to disentangle space applications from their public-sector origins. For the foreseeable future, it is difficult to understand how space systems will be developed and operated as totally private ventures without some form of Government oversight or involvement.

Product, Process, and Service Innovation

Much of the current discussion concerning space industrialization has focused on the unique characteristics of the space environment and the new product, process, and service innovations that may result from the use of this environment. There is a tendency in such discussions to regard space industrialization as an undifferentiated set of activities, each offering equal opportunities for investment and commercialization. Important distinctions concerning the sophistication and reliability of the relevant technologies and the presence or absence of a market for the proposed innovation are often overlooked. Consequently, space activities that have pregent commercial potential are often confused with those that merely offer productive avenues for basic research. It is important to review a few of the current and proposed space activities in order to understand how their many individual differences affect their potential for successful commercialization. The following section will take a brief look at satellite communications, remote sensing and space transpiration, with a more detailed examination of the commercial prospects for materials processing in space.

Satellite Communications

To understand how communications satellites fit into the overall scheme of space industrialization, it is necessary to view this technology in an historical perspective and to disregard for the moment its present complex manifestations. In the late 1950's in the United States there was a great deal of Government and private interest in satellite communications. The private sector, notably AT&T, was keenly aware of the commercial potential of such systems and was proceeding with its-own research while keeping a close watch on the progress of both the National Aeronautics and Space Administration (NASA) and the Department of Defense. The research of AT&T eventually resulted in the design and construction of Telstar, the U.S. first civilian active repeater satellite.[1]

The fact that AT&T initiated and funded its own satellite research program without first obtaining from NASA a guarantee for financial or technical assistance is a point that deserves some scrutiny. Corporate investment in new product development is generally undertaken only after a critical appraisal of the relevant technology, the anticipated development cost and anticipated return, and the market demand. AT&T's decision to extend its communications network into space was no exception to this general rule.

From the technological point of view, communications satellites had three distinct advantages over many of the space projects that are presently under consideration. First, a communications satellite is, or rather can be, a very simple device. All that is required is the proper placement above a specific Earth point and the ability to reflect either radio or microwaves to another Earth point.[2]

Secondly, much of the research and testing of a communications satellite could be done on the ground. This meant that development time would be faster and research costs would be lower and more predictable.

Finally, corporate developers had the assurance of knowing that when their product was finished it would provide them with three distinct advantages over ground-based communication systems. These advantages are insensitivity to distance, broadcast ability, and flexible routing. Distance insensitivity means that the cost of communicating between two points remains the same no matter how far they are apart. This must be contrasted with communications by cable, where the cost is nearly proportional to the length of the cable. A satellite is also capable of broadcasting simultaneously to several Earth points, whereas a cable can carry communications only between two specific locations. Flexible routing means that a satellite's circuits can be switched to different routes as traffic patterns change. Terrestrial circuits, on the other hand, must be plentiful enough to meet peak demands on specific fixed routes,

Another important factor that went into AT&T's decision to invest in satellite communications was its dominant market position. In addition to its large domestic telephone market, by the time Early Bird was launched in 1965, AT&T owned a majority interest in all the transatlantic cables connecting North America and Europe. Unlike the firms which today may be considering some type of enterprise in space, AT&T had a strong hold over the market it was about to enter. In a similar vein, Western Union's development of "Westar," the first domestic satellite system, should be viewed in light of Western Union's position as the sole domestic telegraph carrier. Its decision to offer domestic satellite service proceeded in large part from its evaluation that a market for this specialized service existed.

In the early 1960's, communications satellites were also attractive from a financial point of view. A Rand Corp. report published at this time had estimated that a low-altitude satellite system would cost approximately $8,500 a year per channel, compared with $27,000 for a new underwater cable system.[4] Though these projections were not entirely accurate, the commercial results of the use of communications satellites are reflected in the history of transatlantic telephone charges. In 1966, immediately after the first com-

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[1] D. Smith, *Communications Via Satellite,* 1976, p. 82.

[2] Using this basic concept, the U.S. Army Signal Corp, in 1945, undertook project Diana, which was an attempt to use the Moon as a passive reflector of radio signals. This research led to the development, in 1959, of a two-way transmission system between Washington and Hawaii. Ibid., p. 30.

[3] M. Kinsley, *Outer Space and Inner Sanctums, 1976,* p. 131.

[4] D. Smith, op. cit., p. 67.

munications satellite went into operation, monthly charges for transatlantic phone circuits dropped sharply and have continued to fall since that times This reduction in price reflects the fact that satellites are a cheaper, more efficient means by which to accomplish long-distance terrestrial communications.

Remote Sensing

Remote sensing of the Earth from space is the second of the space applications with near-term commercial potential. (For a more detailed discussion of this subject see ch. 3.) When Landsat 1 was launched in July of 1972, the U.S. Government owned and operated, through NASA, both the space and ground segments of the system.[6] Recently, responsibility for the operation of a civilian remote sensing system has been assigned to the Commerce Department's National Oceanic and Atmospheric Administration (NOAA). Eventually NOAA will take over the operation of the Landsat spacecraft now operated by NASA with the ultimate goal of transferring both the space and ground segments of the system to the private sector.

Though there is a considerable amount of interest in remote sensing, it is unclear whether the private sector can accept the full responsibility for a complete Earth resource system. There are three main reasons for this reluctance.[7] The first is that, unlike satellite communications, the market for remote sensing is quite new. Though it is potentially strong, it is now too undefined to allow accurate projections of return on investment. The second problem is that the Government is now and will probably remain the largest user of remotely sensed data. The success of private enterprise in this area will depend on whether or not the Government decides to satisfy its civilian remote sensing data requirements from a private operator, the price it will pay for such services and whether the Government will agree not to compete with the private sector. The third problem is that the prices now charged for data will not support systems costs. Up until this time the costs of data have reflected only the marginal cost of reproduction. This has been possible because NASA, during the R&D phase of its remote sensing program, subsidized all of the operational costs. In the near future the French and Japanese may be operating government-subsidized remote sensing satellites. If this is the case, U.S. firms, whose price structures must reflect the total costs of operations, may not be able to compete in the world market.

As a result of these factors, it is unlikely that the private sector will be interested in owning the remote sensing system as presently configured until investors perceive that the probable return on investment is at least comparable to that available from other risk-investment opportunities. It should be noted that Landsat may not be an appropriate model by which to gage the costs of a commercial remote sensing system. Because Landsat is an R&D system, it is encumbered with many costs and inefficiencies that could be eliminated in a commercial system developed to meet specific user needs with appropriate and cost-effective technology.

At this time corporations are involved only indirectly in remote sensing from space. In addition to the products and services developed and manufactured by the aerospace industry for the various Federal programs, the private sector has also developed and provided analytical hardware, software and services to private and Government users.

presently, there are over 50 organizations in the United States involved in the analysis of remotely sensed data on a commercial basis. These organizations use the imagery acquired from space to evaluate areas of the Earth's surface for such varied purposes as hydrocarbon resource potential, estimating crop production and land use surveys. Several firms are also selling hardware designed to process remotely sensed data.

[n the near future, it would appear that private involvement in remote sensing will be limited to providing the above mentioned hardware sales and "value-added" services. Only when the markets are sufficiently large, with data prices reflect-

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[5] J. E. Schnee, "inventory of Space Activities (Economic), " presented at the Symposium on *Space Activities and Implications,* Institute of Air and Space Law, McGill University, October 1980.

[6] For a brief history of the Landsat program and technology see: National Academy of Sciences, *Resource Sensing From Space, 1977.*

[7] *See* generally: An Interagency Task Force "Private Sector Involvement in Civil Remote Sensing, " June 15, 1979.

ing the true costs of acquisition, can the private sector be expected to own and operate remote sensing systems.

Space Transportation

Recently there has been considerable discussion concerning the possibility of establishing privately owned launch systems. This discussion has focused on three alternatives: 1) commercialization of the U.S. present expendable launch vehicles; 2) transfer of shuttle ownership and/or operation to the private sector; and 3) private development of a new generation of low-cost expendable launch vehicles. At present, the absence of a comprehensive Government policy which favors and encourages the participation of the private sector in launch system ownership has inhibited such developments.

The present expendable launch vehicles (ELVS), such as the McDonnell Douglas Delta and the General Dynamics Atlas-Centaur, are already operated on a quasi-commercial basis. These vehicles are commonly purchased through NASA by communications companies for communications satellite launches. Although the vehicle is launched by the Government, its cost and and those related ground services are borne by the private sector purchaser. The transition from the quasi-commercial provision of launch services to a purely commercial system may be difficult to accomplish. Because the Government has historically developed and operated launch vehicles and presently owns all of the sophisticated U.S. launch facilities, some form of Government-industry cooperation would seem to be a necessity. This, in itself, should not be a cause of concern because, as the aeronautics industry proves, Government and industry can work together to the mutual benefit of each. The problem that does arise, however, is that in certain instances the goals of the Government are not those of industry.

For example, the present Government commitment to the shuttle entails several costs which NASA, at present, does not intend to recover from shuttle users. This type of subsidy allows the shuttle (and likewise the Ariane launch vehicle of the European Space Agency (ESA)) to be priced in a manner that does not reflect the true costs of operations. From NASA's standpoint as an R&D agency this subsidy may be desirable because it encourages the use of a newly developed system. However, the shuttle price then becomes the price the private sector must match in order to compete for commercial payloads. Because a commercial operation must not only meet its costs but also generate a profit, it is questionable whether proven technology such as the U.S. ELVS can be commercially competitive in the absence of some form of Government assistance. Such assistance could come in the form of a promise of a certain number of government launches, access to government launch facilities or more traditional incentives such as tax breaks. However, given this country's long-term commitment to the shuttle, it seems unlikely that such assistance will be forthcoming.

There has been some discussion concerning the possibility of converting surplus military rockets, such as the Polaris or Minuteman, to commercial launch vehicles. Given that the Government would support such a plan, the main advantage to using these vehicles would be their extremely low cost. There would, however, be a number of disadvantages. Because these vehicles do not have the power to carry large payloads to geostationary orbit, they could not be used to launch many of the newest communications satellites. Furthermore, the fact that these launch vehicles would be surplus equipment operated by nongovernment personnel would make it difficult, at least initially, to obtain launch contracts from companies accustomed to the security of dealing with NASA. It would be unlikely that customers would be willing to entrust valuable payloads to an unproved private company particularly if adequate launch insurance were not available.

Transfer of the shuttle to the private sector has also been considered. Such a decision would involve a major policy shift on the part of the Government, with substantial institutional and financial reprecussions. Important questions would have to be examined: 1) what part, if any, of the shuttle development costs should the Government attempt to recoup; 2) could the national security needs of the United States be met by a privately owned shuttle; and 3) could a private shuttle compete in the international arena with foreign, subsidized launch systems? None of these problems necessarily prevents the shuttle from being owned and operated by the private sector; however, the resolution of any of these problems requires a substantial degree of Government involvement.

Several private firms have also consitiered the possibility of developing a new generation of low-cost launch vehicles. However, even using proved ELV technology, the high cost and long development time associated with such an endeavor have so far prevented the successful development of such a vehicle. Were such a firm to be technologically successful, commercial success would still depend on a positive Government attitude toward such an enterprise. Questions such as launch safety, payload regulation, acquisition of new launch facilities, and launch agreements with foreign governments would still require resolution. The time and expense involved in developing a private launch system combined with government delays and regulatory complications may well create too heavy a burden for the private sector to carry alone.

Materials Processing in Space (MPS)

As indicated earlier in this report (see ch. 3), the unique properties of outer space, most notably microgravity, are amenable to a number of industrial processes. Some of the organic and inorganic materials that may in the future be processed in space have already been mentioned above. it should be noted, however, that the nascent state of MPS technology and the lack of clearly defined markets place materials processing in a long-term, high-cost, high-risk category that is generally beyond the interest and financial capabilities of most private commercial concerns. It is unrealistic to expect any **major** financial commitments from the private sector until the technical capability and economic feasibility of new space processing techniques have been demonstrated. At least for the near future, the responsibility for proving the technical and economic feasibility of new space technologies will rest on the Government acting, either alone or in joint ventures with the private sector. Because of the emphasis NASA placed on commercializing MPS technology, it is useful to examine this space application in some detail.

BARRIERS TO COMMERCIALIZATION OF MPS TECHNOLOGY

Most of the products and processes presently being considered for development in space are, at best, in the basic research stage of the innovative process. Though it would be correct to say that the private sector will begin to invest in space industry only after achieving a more sophisticated understanding of how materials and processes behave in space, such an analysis identifies only one aspect of its reluctance. A number of commercial, legal, and organizational factors must also be considered.

Few ***attractive*** investments.—of all the barriers to process innovation in space, the most important is that the ideas for new products and processes that have been suggested simply are not very attractive investments. Industrial R&D projects are a discretionary expenditure, and therefore must compete for corporate capital with other investment opportunities. A project's ability to compete is a function of the amount of risk it involves, its estimated front-end costs, and its foreseeable rate of return.

The risks involved in space innovation are considerable. For example, several pharmaceutical products have been identified that may be produced either more cheaply or with greater ease in outer space. However, before any of these products could reach the market a number of significant problems would face the manufacturer. First, there would have to be a period of ground-based R&D where the techniques to be employed in space would be developed. Next, the process would have to be verified in space. This problem depends on the availability of NASA test facilities, such as the shuttle, which in turn depends on how the current political and economic environment affects NASA funding. Because the Government has the right to terminate contracts unilaterally, a company that has spent millions of dollars on R&D could find itself without access to shuttle flights. Though the Government might have to reimburse a client's costs on a contract it canceled, such reimbursement would not include the opportunity costs—that is, the costs of devoting resources to a space processing program in place of some other business opportunity. If the process were verified in space, Food and Drug Administration (FDA) approval would still be necessary before the new pharmaceutical product could be marketed, and–depending on the complexity of the manufacturing process—new legal and regulatory agencies might be necessary.

Even if all of these R&D hurdles could be cleared, the economic success of a drug manufactured in space would still depend on the company's ability to produce and sell large enough specific annual quantities of a new product. It is unlikely that the shuttle, as it is presently configured, could guarantee such a requirement. Long-term MPS facilities based in space and dedicated to commercial space processing neither exist nor are planned for the near future.

It is by no means certain that a firm wishing to manufacture a product in space would have to face all of the complications enumerated above. The results of MPS experiments undertaken over the next 2 to 5 years may reveal many commercially attractive opportunities for products or services that can be performed on the shuttle as presently configured. Nonetheless, the risks involved in space-based product research do create a substantial barrier to investment.

In addition to the technical and institutional risks involved in utilizing the space environment, there are also uncertainties regarding cost and development time. The present shuttle pricing schedule does not reflect the true costs of operations. A recent General Accounting Office report has suggested that NASA should void its pricing policy (except for those launches that have legally binding agreements) and charge "substantially higher prices for future Iaunches."[8] Uncertainties as to the price of future shuttle missions make it difficult for business planners to estimate the cost of space-based product development.

Firms interested in investing in a new product must estimate that product's potential rate of return. When considering the rate of return that a space-based industry might generate, one must take into account the development time of such a project. Because a dollar held today has greater buying power than a dollar held in the future, the dollar that is anticipated in the future must be "discounted" to reflect its actual value in today's dollars. This means that the longer any project takes from its R&D phase to commercialization, the greater the profit must be when the project begins to make money. This is particularly true during times of high inflation and high interest rates. The combination of technical uncertainties and potential problems in obtaining the shuttle flights necessary for project verification makes it difficult to predict the development time for space-based projects. The combination of high-cost, high-risk, long-payback time and uncertain rate of return makes it difficult for space-based projects to compete for internally generated corporate capital with other, more traditional, investment opportunities. Similarly, conventional methods of financing such as equity capital or borrowing may not be available, and the degree of risk involved here may also discourage the flow of venture capital into this area. g

Uncertainties as to value of space environment.-In addition to the view that there is little to be done in space, there is a tendency in the business community to believe that whatever can be done in space can also be done on Earth. Though it is often stated that the microgravity of space is fundamentally different from Earth gravity and cannot be duplicated, new technologies have been developed which do minimize the effects of gravity on Earth. Examples of this fact can be seen in recent developments in containerless processing and in the manufacture of latex polymers.

It is believed that one of the advantages to in-space manufacturing will be that materials can be processed without picking up impurities from the wall of the container that holds them. Recently a U.S. firm working with NASA developed a containerless processing system for making special glass products on Earth. [10] in this system the

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[8] "NASA Pricing Policy on the Space Transportation System," GAO Report to Congress, Feb. 23, 1982.

[9] The Space Industrialization Act of 1979: statement Of Russell Carson at hearings on H.R. 2337, before the Subcommittee on Space Science and Applications, 96th Cong, 1st sess., p. 1767.

[10] Industry Week, Mar. 3, 1980, P. 90.

glass is suspended within a chamber by sound beams in a process called acoustic levitation. Another example of an Earth-based advance that has a space counterpart is the manufacture of latex polymers. It is believed that, in space, latex polymers could be enlarged to as much as 40 microns. Although it had been assumed that the gravity on Earth would limit the expansion of these materials to 2 microns, Norwegian scientists using new chemical techniques have increased the size of latex polymers to 10 microns.[11] Though neither process functions as efficiently as would similar space-based processes, they are accomplished without the enormous expense and administrative complexity of space-based manufacturing. Industry will be hesitant to invest in space as long as there is at least some hope that Earth-based manufacturing techniques can accomplish similiar results.

Prior investment in Earth technology.–Even if industry could be sure of the commercial viability of some of the projects that have been proposed, its prior investment in Earth-based technology may make it reluctant to pursue new innovations in space. Radical innovation, whether in space or on the Earth, usually means discarding expensive equipment before a company has had time fully to depreciate it. For example, it has been suggested that the U.S. auto industry's enormous investment in automating the manufacture of cast iron brake drums probably delayed by more than 5 years its transition to disc brakes.[12] Some companies prefer safer methods of maximizing profit, such as advertising, market research, and automation, rather than risking investment in new products and processes. The majority of industrial product and process development is directed at reducing costs and increasing profits in the short run. For this reason it is more common for industry to seek new methods of making existing products more cheaply or marketing them more effectively than to develop new products.

This is not the first time that this conflict between old technology and new has been an issue in the space debate. In the early 1960's, when Congress was trying to fashion an institutional structure and a method of ownership for the Communications Satellite Corporation (COMSAT), there were serious reservations about allowing the existing international communications carriers to invest in the corporation. It was assumed that companies with large investments in existing facilities would be reluctant to take speedy action to implement new satellite systems that would make their existing facilities obsolete. To some extent, a similar concern may be raised regarding companies that could benefit from space-based manufacturing techniques. Even if the product that could be produced in space is better or more efficient than its Earth-manufactured equivalent, a corporation's prior investments may prohibit it from pursuing this new technology.

Intellectual property. -Another potential barrier to process innovation in space is the fact that a large portion of the private sector has no experience in dealing with the Federal Government other than as an occasional vendor of supplies and materials. In the normal course of events, a firm working for the Government is required to submit periodic reports detailing the progress of its work. Such requirements are at odds with the usual desire of industry to protect its investments in R&D by refusing to disclose details or results of current research. Industry is also concerned that a business relationship with the Government could result in the loss of certain intellectual property rights.

The Freedom of Information Act[13] raises a number of problems concerning the protection of data and proprietary rights. It requires the disclosure of "Government records" upon request, unless the records fit into one of the narrow exceptions to the act. Information obtained under a guarantee of confidentiality may be protected and "trade secrets" are a recognized exception to the act. A company working with NASA must carefully screen that which may become a "Government record" and be sure that if sensitive information becomes "Government record" it qualifies as one of the exceptions to the disclosure requirements.

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[11] Ibid.

[12] Robert H. Hayes and William J. Abernathy, "Managing Our Way to Economic Decline" *Harvard Business Review,* July and August 1980, p. 70.

[13] 5 U.S. 552.

Several legal issues may inhibit the private sector's involvement in the innovative process in space. The first concerns the question of ownership of the patent rights to new products and processes discovered during the course of a joint endeavor with NASA. Section 305 of the 1958 NAS Act states that "whenever any invention is made in the performance of any work under any contract of [NASA], such invention becomes the exclusive property of the United States unless [NASA] waives rights thereto . . . "[14] A strict reading of this section would vest in NASA the ownership of all inventions discovered while working for, or in a joint venture with NASA. Over the last two decades NASA has limited the application of section 305 to activities performed for NASA which have as their main purpose the development of some new product or process. With regard to joint ventures, it has been NASA's position that neither party assumes any obligation to perform inventive work for the other, and accordingly each party retains the rights to any invention that may be made in the course of the venture.[15]

International Law. –In the area of international law, the private sector seems to be troubled by the growing use in international treaties of "common interest" clauses such as the Common Heritage of Mankind principle which has been discussed at the Law of the Sea Convention and appears in the proposed Moon Treaty.[16] Simply stated, these clauses assert that certain resources, such as the minerals on the ocean floor and on the Moon and the "slots" in geostationary orbit, are presently under the jurisdiction and control of no sovereign power; these resources, being finite and exhaustible, should not be allocated to the developed countries on a first-come, first-served basis, but rather, should be made to benefit all nations. Although these "common interest" clauses have found their way into all the major space treaties, there is considerable uncertainty as to their status within the body of international law. Some writers have suggested that these clauses are merely pragmatic principles without legal force.[17] Others regard them as binding principles which obligate states to be responsive in some form to the interests of developing countries.[18]

The use of "common interest" clauses in international treaties has brought about strong opposition from the private sector. The most common argument heard in this regard is that the concept of equitable sharing is inconsistent with the concept of profit, and in the absence of the profit motive private enterprise cannot be expected to risk capital on space investments. At this stage of space industrialization such considerations have had only a minimal effect on the private decisions whether or not to invest in space.

INDUCEMENTS TO PROCESS INNOVATION IN SPACE

Profit potential. –Though there are substantial physical, economic, and psychological barriers to process innovation in space, certain inducements do exist which may encourage private sector participation in this area. Probably the most important incentive to the private sector is the potential for making a profit. At the present time only ***two*** product areas seem ***to*** offer the combination of technical feasibility and market potential that are necessary for a profitable venture. The first of these product areas is pharmaceuticals.

McDonnell Douglas together with Ortho Pharmaceutical Corp. has investigated the commercial cial potential of several pharmaceutical products, which could be processed by electrophoresis in space, and has entered into a joint agreement with NASA to test this technology. This project has been described by McDonnell Douglas as an "aggressive, well-ordered commercial business venture" in which the combined investment of the pat-ties will be measured in terms of millions of dollars. Clearly McDonnell Douglas and Ortho

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[14] 42 U.S.C. 2451, et. seq.

[15] Space Industrialization Act of 1979: statement of Robert A. Frosch at hearings on H.R. 2337, before the Subcommittee on Space Science and Applications of the House Committee on Science and Technology, 96 Cong. 1st sess., 1979.

[16] *Agreement Governing the Activities of States on the Moon and Other Celestial Bodies,* U.N. doc. A/34/664.

[17] C. Q. Christol, "The Legal Common Heritage of Mankind: Capturing an Illusive Concept and Applying It to World Needs, " XVIII, *Colloquium on the Law of Outer Space, 1976, p. 42.*

[18] S. Gorove, "Limitations on the Principle of Freedom of Exploration and Use of Outer Space," XIII, *Colloquium on the Law of Outer Space, 1973,* p. 74, et. seq.

believe that there is a profit to be made in developing this technology.

Other potentially profitable products that can be manufactured in space are the starting material for electronic devices such as large-diameter crystals. Like pharmaceuticals, these crystals have a high market value per unit mass. The facilities needed to manufacture the basic materials are also small, so that the total orbital mass is low, even for very high production rates. The economic advantage of manufacturing the starting materials for electronic devices in space is less sure than for pharmaceuticals and no one has made a major investment in this technology.[19] It should be noted that the Earth-manufactured electronic devices presently enjoy a sales level of about $16 billion per year with an estimated growth rate of 10 to 15 percent annually for the next 10 years. Such a healthy market is conducive to innovation and may eventually provide the incentive for the private sector to invest in space-based manufacturing techniques.

In addition to products, it is possible that the private sector may find it profitable to offer certain space-based services. The GTI Joint Endeavor Agreement with NASA (discussed below) is based on this assumption. GTI is developing a metallurgical furnace which it hopes to rent to parties interested in the effects of solidification in microgravity. As experience is gained in MPS research, it is likely that other space-based services will be offered by the private sector.

Scientific knowdedge. –Another reason that the private sector may wish to invest in process innovation in space is to gain a better understanding of present Earth-based manufacturing techniques. For example, methods now used for the commercial growth of large crystals have been developed empirically with little theoretical understanding of what occurs at the microlevel during growth. It is possible that significant improvements in Earth-based crystal growth could result if low-gravity experiments were to provide a better theoretical understanding of the growth process. In a similar vein, the John Deere Corp. has entered into an agreement with NASA to study the solidification of cast iron. The purpose of this research will be to gain a better understanding of how the graphite formation of cast iron influences the metal's properties. It is expected that low-gravity experiments will provide insights into this question which, though obtained in space, will have practical use on Earth.

***Institutional incentives.* —In** order to encourage private involvement, NASA has established the Commercial Applications Office in its MPS program. This office forms a bridge between NASA and the private sector which provides assistance to the industrial user and suggestions to NASA on how the commercial growth of MPS might be advanced. Joint projects between industry and NASA are "no exchange of funds" agreements to cooperate in a given area with each party assigned specific tasks to accomplish. The Commercial Applications Office has developed three basic levels of working relationships with private organ izations:

***Technical exchange agreement (TEA)* .–For** companies interested in applying microgravity technology, but not ready to commit to a specific space flight experiment or venture, NASA has developed TEA. Under a TEA, NASA and a company agree to exchange technical information and cooperate in the conduct and analysis of ground-based research programs. In this agreement, a firm can become familiar with microgravity technology and its applicability to the company product line at minimal expense. Under TEA, the private company funds its own participation, and derives direct access to and results from NASA facilities and research, with NASA gaining the support and expertise of the private company's industrial research capability.

Industrial guest investigators (lGl).–ln an IGI agreement, NASA and industry share sufficient mutual scientific interest that a company arranges for one of its scientists to collaborate (at company expense) with a NASA-sponsored principal investigator on a space flight MPS experiment. Once the parties agree to the contribution to be made to the objectives of the experiment, the IGI becomes a member of the investigation team, thus adding industrial expertise and insight to the experiment.

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[19] Materials processing in Space, report of the Committee on Scientific and Technological Aspects of Materials Processing in Space, National Research Council, 1978, p. 40.

Joint endeavor agreement (JEA)-JEA is a cooperative arrangement in which private participants and NASA share common program objectives, program responsibilities, and financial risk. The objective of a JEA is to encourage early space ventures and demonstrate the usefulness of space technology to meet marketplace needs. A JEA is a legal agreement between equal partners, and is not a procurement action; no funds are exchanged between NASA and the industrial partner. A private participant selects an experiment and/or technology demonstration for a joint endeavor which complies with MPS program objectives, conducts the necessary ground investigation, and develops flight hardware at company expense. As incentive for this investment, NASA agrees to provide free shuttle flights for projects which meet certain basic criteria, such as technical merit, contribution to innovation, and acceptable business arrangements. As further incentive, the participant is allowed to retain certain proprietary rights to the results, particularly the non patentable information that yields a competitive edge in marketing products based on MPS results. However, NASA receives sufficient data to evaluate the significance of the results, and requires that any promising technologies be applied commercially on a timely basis, or published.

NASA has developed these three types of working relationships in order to attract private-sector interest at varying investment levels. It hopes that firms with limited funds and cautious R&D policies may start out with a TEA or an IGI and, if in-space experimentation appears valuable, upgrade their cooperative efforts to a JEA.

Another interesting method for attracting and maintaining the interest of private enterprise in space-based manufacturing is the proposed Space Industrialization Corporation (SIC) .20

The bill which proposed SIC declares that it is a finding of Congress that "space activities have matured to the point where the attributes of space are generally understood" and a "number of potential uses of the properties of the space environment are already known to have commercial applications. " In light of these findings, the bill proposed the creation of a mixed-ownership corporation funded initially by Congress to "promote, encourage, and assist in the development of new products, processes, services, and industries using the properties of the space environmerit. "

As a mixed-ownership corporation, SIC would be managed by a Board of Directors appointed by the President, consisting of a chairman, three qualified members of the executive branch, and eight members from the private sector. The financing of SIC would take the form of a "Space Industrialization Trust Fund." Congress would provide this fund with $50 million per year for the first 2 fiscal years and then additional sums as might be necessary.

When the Board of Directors determined that the corporation was operating "successfully, effectively, and profitably," then it would take steps to transfer SIC from a mixed-ownership corporation to pure public ownership. As a publicly held corporation, the financing for SIC would derive from issuing capital stock and selling nonvoting securities and bonds.

One would assume, in light of the financial difficulties involved in private sector participation in materials processing in space, that a proposal such as SIC would meet with general approval. This, however, has not been the case. Many have hastened to point out that though the proposed SIC is a step in the right direction, the idea in its present form contains some serious problems. The problems most often cited by those opposing SIC in its present form are: 1) that such a proposal is premature in that the attributes of space are **not** generally understood; and 2) that it may interfere with the activities of NASA, particularly its MPS program.[21]

Government Encouragement of Innovation

Government involvement in the process of innovation raises important questions as to the appropriate roles of the public and private sectors

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‘“’’ The Space Industrialization Act of 1979," H.R. 2337.

[21] The Space Industrialization Act of 1979, op. cit., p. 64.

in the development and operation of new technology. Ordinarily, the private sector bears the total responsibility for funding R&D intended to be incorporated into commercial systems. However, over the past several decades the Government has provided significant support, not only for basic research but also for applied research, technology and systems development, and even demonstration projects in the aerospace industry. In each of these instances, the Government role in the process of innovation was determined by the complex interaction of such variables as: the sophistication of the technology involved, its perceived importance to national goals, the structure of the market to which the technology is addressed, the level of industry interest, and the ability of the private sector to develop the relevant technology without Government support.

The following section presents three different examples of how Government intervention has been used to direct and encourage technological innovation.

Aeronautics

An often-cited example of Government success in moving new technology out of its own control and into the private sector, is NASA's aeronautical research program. This effort began as a direct outgrowth of the program of the National Advisory Council on Aeronautics (NACA), initiated in the mid-1920's and formalized in March 1946 by the National Aeronautical Research Policy. This policy, promulgated to clarify the relationship of NACA with other R&D agencies, charged NACA with the responsibility for conducting "research in the aeronautical sciences." By comparison, the policy assigned to industry the responsibility for the "application of research results in the design and development of improved aircraft equipment." In other words, the Government agreed to assume the responsibility of early applied research but product development would remain the responsibility of the private sector. This approach seems to have worked rather well, inasmuch as the history of U.S. civilian aviation is crowded with examples of technology which found its way into commercial use after initial, early research at government expense. For example, ***super critical airfoils,*** the ***high bypass tubofan jet engine,*** the ***microwave Landing system,*** the ***turboprop engine,*** and many others were all introduced for commercial exploitation in the American market after years of fundamental R&D work by NACA and later by NASA.[22]

In its generally successful efforts to launch government-developed aviation technology into the private sector, NASA exploys two concepts for identifying at what point the development of a given technology should become the responsibility of the private sector. These two concepts are "technology validation" and its logical followup, "technology readiness."[23] The former describes the state of a technique, still under investigation, when its essential performance characteristics have been proved but before there is confidence in the level of costs associated with fabrication of that device or technique under investigation. The latter term, "technology readiness" is employed to describe a technology that has been demonstrated to have a reasonably high probability of resulting in a commercially manageable fabrication process. Note that NASA does not actually design a fabrication process, but only "certifies" in an informal way that the road seems clear for a private firm to do so. In this sense the technology is "ready" for the private sector. NASA has performed the generic R&D that is necessary to prove the worth of a new application of engineering science to aviation technology. It does this both for the particular technology in question and also, if the success of the first stages warrants, for the fabrication or manufacturing technology necessary to produce the innovation. If at this point industry wishes to shoulder the risk of further specific R&D (which is usually much more expensive than the preliminary, generic R&D) based on its judgment of level of expected return on its investment, it may do so with a much greater degree of confidence than if it were to start a technology validating process from scratch. Essentially, this process is one of lowering the threshold of risk for private investment in a new and promising technical development. Doing so at public expense is justifiable so long as there

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[22] NASA, The High Speed Frontier: Case Histories of Four NACA Programs (1980).

[23] Office of Technology Assessment, *Impact of Advanced Air Transport Technology,* Part 1; pp. 10, 34, 1979.

are significant public as well as private benefits to be exploited in the innovative product, service, or process. It should be pointed out, in respect to this last notion, that in order for NASA to be confident of the existence of a "significant public benefit" to be had from its generic technology development efforts, a well-developed market for civilian aviation services was an important given condition. The importance of a well-developed market and its effect on Government R&D is examined in greater detail in the following discussion of communications satellites and materials processing in space.

Communications Satellites

Communications satellite technology from its inception was pursued with enthusiasm by the private sector. The initial Government position articulated during the Eisenhower administration was that NASA should "take the lead within the executive branch both to advance the needed research and development and to encourage private industry to apply its resources toward the earliest practicable utilization of space technology for commercial civil communications requirements . . . "[24] At this time AT&T's position as the sole U.S. international telephone carrier and its financial ability and willingness to commit funds to the development of communication satellites made it the obvious industry partner for NASA efforts. By September 1960, AT&T was ready to request that NASA clarify its policies concerning aid to companies working to develop communications satellites[25] and had already contacted the Governments of France, Britain, and Germany about plans for low-altitude satellites to provide transatlantic telephone and television service.[26] Hughes Aircraft had also contacted NASA to express its interest in, and ideas for, communications satellites.

Had the Eisenhower administration's policy been continued, it is almost certain that the private sector would have undertaken the commercialization of satellite communications. With NASA supplying technical assistance and FCC regulating such communication under traditional guidelines, it is probable that the development of this technology would have proceeded without the creation of an organization such as COMSAT.

COMSAT was the product of public policy considerations and not of the marketplace. With the Kennedy administration came a strong commitment to the space program as a means to enhance U.S. prestige and security. It was felt that satellite communications could be one area of early U.S. competence. As a result an additional $10 million was added to the 1961 NASA budget for communications development.

The addition of these funds had several effects on the communications satellite innovative process. The most obvious effect was that NASA had the funds and the mandate to "push" communications technology to maintain U.S. leadership in this field. A peripheral, though seemingly intended result was a postponement of private sector investment in this technology. This development reflected the decision of the Kennedy administration to assess the policy implications before placing the development of communications satellites in private hands. It was also consistent with the administration's desire to keep satellite communications responsive to Government policy and its cautious approach to what seemed an imminent AT&T monopoly in international communications.

In a curious inversion of the normal chain of events, the Government used its ability to subsidize innovation to retard the process of commercialization rather than to speed it. The Government wished to ensure that any transfer of technology occurred under conditions that would be responsive to foreign policy considerations. This desire was accomplished by the statutory creation of the unique public/private COMSAT.[27]

COMSAT is a private corporation with a monopoly in the business of international satellite communications. The Communication Satellite Act of 1962 provided that ownership and financing of the corporation would be accomplished through the issuance of capital stock. The act originally reserved 50 percent of the stock for purchase by communications common carriers au-

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[24] D. Smith, p. 70.

[25] Ibid. at 70.

[26] Ibid.

[27] Communication Satellite Act of 1962, 47 U.S. C. 721.

thorized by FCC. The act also initially provided that the Board of Directors was to be composed of six members elected by the common carrier stockholders, six elected by the rest of the stockholders, and three appointed by the President with the advice and consent of the Senate.[28] In this manner Congress sought to insure that the Government retained some degree of internal control over the organization.

The COMSAT Act also provides certain external controls which allow the Government to regulate and direct COMSAT'S activities. Section 201 (a) of the act grants the President the authority to undertake such activities as aiding the planning and development of the system, reviewing all phases of development and operation, supervising the relationship of the corporation with foreign governments, and insuring foreign participation in the system. Further, the act gives FCC the power, among other things, to ensure competition in the procurement of equipment and service, to regulate technical compatibility between satellites and ground stations, to set ratemaking procedures, and to approve technical characteristics of the system.

The Government's support of innovation in communications satellite technology benefited COMSAT in two ways. First, the technology eventually transferred to the new corporation was more advanced than that which would otherwise have been available for commercialization in the early 1960's; second, this technology was developed at the public expense. The complicating factor is that because COMSAT was not solely a commercial venture founded in response to market demands but rather a hybrid organization designed to implement public policy, the responsibility for innovation in satellite technology has never been clear. After COMSAT was established, there was considerable disagreement as to what role NASA should play in further communications satellite research and development. Many felt that COMSAT, as a private entity, should take the initiative and the risks associated with the evolution of the communications satellite. Others believed that NASA should continue its R&D role because the NAS Act of 1958 mandated it to ensure U.S. leadership in space technology. NASA's position in the mid-1 960's was that it should be allowed to continue research in advanced technology, whereas COMSAT'S R&D would be directed to establishing the initial operating systems.

Using this and similar arguments, NASA continued to receive funding and to do communications satellite R&D until January 1973. At this time, the combination of NASA budget limitations and the success of commercial satellites for both international and domestic service led NASA to phase out its work on advanced communication systems.

The Joint Endeavor Agreement

The primary method by which the Government is seeking to encourage private sector participation in MPS research is through innovative NASA/industry relationships such as the Technical Exchange Agreement (TEA), the Industrial Guest investigation Agreement (IGIA) and the joint Endeavor Agreement (JEA). Since JEA requires the greatest commitment on the part of NASA and the private sector participant, it is useful to examine this arrangement, its problems, and its potential for success.

As of January 31, 1982, there were two jEAs in effect. The first of these agreements, referred to earlier, was with McDonnell Douglas Astronautics Co. (MDAC) and the second is with the GTI Corp.

The subject matter of MDAC/JEA is a process called continuous flow electrophoresis (C-F-E). This process separates materials in solution by subjecting them to an electrical field as they flow continuously through a chamber. The McDonnell Douglas C-F-E experiment will use the shuttle, at NASA's expense, to develop and demonstrate the applicability of that process to the creation of marketable quantities of pharmaceutical products. Ortho Pharmaceutical Corp. has been selected by McDonnell Douglas as a partner in its materials processing business venture. Ortho has completed a detailed market analysis on the first C-F-E candidate product to be produced in

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[28] The Communication Satellite Act was amended in 1969. Sec. 303 (a) now states that if the shares of voting stock held by the communications common carriers is less than 8 percent, the common carriers are not allowed to elect directors separately (47 U.S.C. 73 3(a)), Presently, the common carriers hold less than one-fourth of 1 percent of the total shares outstanding.

space. The corporation is now developing a detailed animal test program for the product, to be followed by a clinical test program. "Substantial sums of money" (in the tens of millions of dollars) have been and will continue to be invested by both parties in the venture. According to MDAC, optimization of C-F-E ground units has been completed, and fabrication of apparatus for space flight demonstration onboard the shuttle in 1982 is now under way.

In addition, the conceptual design of a precommercial space flight pilot plant has been initiated. Present plans call for pilot plant demonstration in 1985/1 986, and maintaining this schedule should result in commercial operation by 1986 or 1987.

The subject of the JEA with GTI Corp. is a metallurgical furnace. GTI's furnace is a 200-lb computer-controlled chamber that will be flown in the cargo bay of the shuttle. The furnace will have 37 compartments for the melting and resolidification of some 220 alloy samples. Should this JEA prove the technical and commercial feasibility of this furnace, GTI will market its ability to manage metallurgical experiments in microgravity to interested public and private sector research organizations.

The JEA requires GTI to develop this furnace and NASA to test it on four shuttle flights. The first flight is presently scheduled for the third quarter of 1984.

Because MDAC/JEA has, and probably will continue to serve as a model for future JEAs, and since the industry/Government relationship established in this agreement differs drastically from the Government's relationship to COMSAT, it is useful to scrutinize the structure and purpose of this agreement.

To create a climate suitable for commercialization in the MDAC case, the first JEA had to address the following issues:

- ***ExcLusivity.*** — In return for MDAC's promise to make results of the work available to the U.S. public on reasonable terms and conditions, NASA agrees to refrain from entering into similar joint endeavors or international cooperative agreements directly related to the development of processes that would compete with those resulting from the MDAC endeavor. NASA is not precluded, however, from selling flight time on the shuttle to any other organizations wanting to conduct the same or similar experiments.
- ***Patent and data*** rights.–NASA will not acquire rights in inventions made by MDAC or its associates in the course of the joint endeavor, unless MDAC fails to exploit the inventions or terminates the agreement, or unless the NASA Administrator determines that a national emergency exists involving a serious threat to the public health.

  In the event that inventions or improvements are made during the joint endeavor, MDAC need not report these to the Government. Records will be retained by MDAC and, if requested by NASA, the company will provide a brief description of the invention. Such description is protected as data or a trade secret if appropriate.
- ***Confidentiality.*** –The JEA requires that data supplied by MDAC shall not be related outside the Government, except after notice to the originator and agreement by the recipient to protect it from unauthorized use and disclosure.
- ***Recoupment.*** —Lastly, to provide the financial incentive for MDAC'S investment, the jEA explicitly recognizes MDAC'S right to a "fair return on investment." Coupled with patent and data rights provisions of the JEA, a "fair return on investment" is to be measured by what is obtained in the appropriate industry, including such factors as the high-risk, long-term nature of the investment.

It is apparent from this brief review that the Government role in MPS is significantly different from its role in the development of aviation and communications satellite technologies. In part this can be attributed to the fact that the markets and technology for MPS are still in an embryonic stage. In addition, research in communications satellites and civilian aviation can be conducted with only minimal recourse to Government facilities and the commercial operation of these technologies can be accomplished with little

Government oversight. MPS research and product development, on the other hand, are still highly dependent on Government facilities. Should such research result in a marketable product, it is unclear how commercial MPS operations could proceed without close Government cooperation. For the near future, the JEA appears to bean important tool for continuing the unique Government/industry relationship which is essential to the development of a mature MPS industry.

OTHER SPACE-RELATED COMMERCIAL ACTIVITIES

Although this chapter has focused primarily on the private sector's involvement in fields of communications and materials processing, with a less detailed look at remote sensing and space transportation, it should be noted that the private sector has several other opportunities for space-oriented, profitmaking activities. Some of the more important of these activities are discussed below.

Financing Space Ventures

Private banking institutions may have a role to play in the future financing of both governmental and nongovernmental space programs. Because the Government has played the lead role in developing space systems, the involvement of private financial institutions has been rather limited. This is particularly true in the United States, and it seems unlikely that any significant changes will occur in the near future. The situation in Europe is slightly different, in that, though the space projects are primarily funded by the governments, European banks have been involved in these projects as shareholders and as a source of loan capital .29

Financial institutions have generally been reluctant to invest large sums of money in high-risk, long-term space projects of the private sector. As new products are refined and their value as investments proved, financing of private space activities will become more common. Recently, for example, financial institutions have been willing to fund the purchase of satellite transponders because communications satellites have come to be regarded as relatively safe and attractive investments. The cost of transponders (approximately $10 million to $15 million) is a relatively small part of the cost of the satellite, and insurance covering both interruption of service and business loss can be purchased to protect this investment. In addition, by using sale/leaseback arrangements, the tax benefits that accrue from transponder ownership can be sold to a third party.

Presumably, other space technologies will follow the path that communications satellites have followed over the last two decades. As these technologies become more reliable and new financial arrangements allow the burden of their cost to be spread out among more investors, it is certain that the role that private financial institutions play in the commercialization of these technologies will increase.

Though private financial institutions have been reluctant to participate in space ventures, it is possible that innovative financial arrangements such as the R&D limited partnership may provide funds in this area.[30] Basically stated, an R&D limited partnership is a partnership formed for a specific purpose, such as the development of a new product. This arrangement provides important tax advantages, in particular that participants may offset their investment in the R&D limited partnership against their current income, even if the latter was derived from an unrelated source. GTI intends to rely heavily on this mechanism to finance its JEA with NASA. Should the GTI experience be favorable, there is no reason why the R&D limited partnership could not be used to finance other private space ventures.

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[29] G. Mazowita, "Space Industrialization, Programs, Policy, and Private Enterprise, " Center for Research of Air and Space Law, McGill University, June 1981, p. 60.

[30] " Limited Partnerships: Profits and Danger, " *Commodities,* VII (March/April 1978), 46; "Tax Classification of Limited Partnerships," *Harvard Law Review XC (1975), 745-762;* "Tax Classification of Limited Partnerships: The IRS Bombards the Tax Shelter, " New *York University Law Review* LII, 2, May 1977, 408-441.

Insurance

The industrialization of space will open up a new market for the insurance industry. As the number and variety of space activities increase, new methods of insuring against unforeseen losses will be needed. If such developments are forthcoming, they will help to make investment in space more predictable and therefore more attractive to the private sector.[31]

Presently, there are four basic categories of satellite insurance available:

- **Ground insurance** covers the satellite, launch vehicle, and related launch equipment until launch attempt or lift-off.
- **Launch failure insurance** commences immediately after lift-off and remains in effect until the satellite achieves a successful orbit.
- **Satellite life insurance** commences when launch failure insurance coverage terminates. Satellite life insurance protects against financial damage caused by loss of orbit or power, or by some technical malfunction. This insurance can be used to cover the replacement costs of the satellite and for economic losses arising from disruption of service.
- **Liability insurance** is used to compensate third parties for bodily injury or property damage caused by the satellite or the launch vehicle.

The types of insurance mentioned above were developed primarily with expendable launch vehicles in mind. The introduction of the shuttle as an operational launch vehicle will present substantial challenges to the insurance industry. On the one hand, the shuttle should increase the number of insurable payloads launched per year, thereby providing a wider base over which to spread risk. This should result in lower insurance costs and increased participation by U.S. and foreign underwriters. On the other hand, the fact that the shuttle can carry several payloads on one flight raises serious questions about the effect that the loss of an entire shuttle might have on underwriters and insurance premiums. Potential liability in such a situation could be as high as $100 million to payload owner and an additional $500 million for third-party claimants.[32] The shuttle, therefore, introduces costs at a level and of a complexity unprecedented in the era of single payloads flown on ELVs. Whether the relatively small group of underwriters who insure ELVs will be able to handle the entire liability for space shuttle operations is an open question.

Hardware sales

Aerospace Industry

The aerospace industry has been the principal private sector participant in commercial space activities. The reasons for this are rather simple. The aerospace industry has the most complete understanding of the advantages and limitations of the space environment and employs large numbers of people who are knowledgeable in space-related technology. Industries that may profit considerably from space technology, such as pharmaceuticals, electronics, and metallurgy, are reluctant to invest in R&D projects that require knowledge, personnel, and support facilities that they do not have.

Another major advantage held by the aerospace industry is its traditionally close relationship with Government. This relationship has had two important consequences. The first, which was mentioned above, is that the industry, often working under Government contract, has been able to develop the expertise to deal with the space environment. The second is that the Government, particularly the military, and the aerospace industry are accustomed to cooperating and relying on one another. Most other industries, however, have little contact with the Government, except in its role as regulator and taxer. Furthermore, normal Government procurement practices, in which the aerospace industry is well-versed, are complex and raise numerous problems regarding the retention of intellectual property.

The structure of the aerospace industry also provides some substantive advantages for devel-

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[31] Satellite Communications, "Condo Satellites: Can We Insure Them?" August 1981, p. 45.

[32] Aviation Week and Space Technology, Apr. 30, 1979, P. 148; Contact, "Insurance Coverage in Outer Space, " December 1977, p. 5.

oping technologies such as MPS. This industry is composed of a few large and essentially nondiversified companies. This structure is a consequence of an environment where competition is limited and funds are available to engage in large but uncertain research projects. The aerospace industry has frequently been involved in long-term projects starting with basic scientific research and resulting 'in innovative new products. This "long-range" perspective which will be necessary for MPS development is not characteristic of many other industries.

New Markets

Until recently, the efforts of the private sector have been directed primarily to supplying the Government's needs for launch vehicles, satellites, and related space hardware. As the user community for such hardware gradually broadens, it can be assumed that an increasingly greater proportion of industry revenues will be derived from nongovernment sales.

The first nongovernment aerospace market to be developed was that of communications satellites. The private sector revenues from this market are on the order of billions of dollars, and estimates for future demand suggest even greater returns. Other opportunities for private sector aerospace sales will flow from the development of the Boeing inertial upper stage and the McDonnell Douglas spinning solid upper stage. These two upper stages will be used to transfer private-sector payloads from the shuttle to the geostationary orbit. Yet another area of potential private-sector revenue will be the sale and lease of multiuser instrumentation designed for MPS research on the shuttle (discussed above in ch. 4). Examples of such instrumentation include the materials experiment assembly (MEA), developed by NASA, and the metallurgical furnace being developed by GTI Corp. in a JEA with NASA. This last type of private-sector involvement may prove to be quite significant. When NASA began the development of the MEA, it anticipated that private institutions might wish to lease this device to conduct their own experiments. Similarly, GTI's development efforts are predicated on the assumption that a substantial market exists for relatively inexpensive space-based research facilities.

A recent marketing strategy report, written under contract for NASA, found that most firms are unwilling to undertake alone the substantial expense involved in the product identification, financing, hardware development and marketing necessary to commercialize space technology .33 The report suggested that NASA should attempt to disaggregate this process in order to facilitate private sector participation in MPS. There is some indication that this process of disaggregation will occur as a matter of course, as experience with MPS grows. The JEA entered into between NASA and GTI tends to support this assumption. GTI's willingness to accept the financial responsibility for one aspect of the commercialization process (in this instance, the provision of a valuable research tool), may provide the incentive for other firms to invest research dollars in this area. Small firms, universities, and research organizations generally do not have the capital necessary to undertake independent research in space. However, if the facilities were available at a relatively low cost, then a broad range of otherwise unaffordable research might be undertaken.

Ground Support Services

Space technology requires a rather elaborate network of ground support services and facilities. As this industry continues to expand, the private sector will almost certainly play a disproportionately large part in the provision of such services. A few early examples of this trend have already begun to appear.

The initial placement and subsequent maintenance of a satellite in its proper orbit requires an elaborate tracking, telemetry, and control network. NASA has previously provided these services, but as space activities become more common, commercial firms could provide them. COMSAT has already begun to do so. In 1979, COMSAT established the first commercial facility for satellite tracking, telemetry, and control services.[34] The COMSAT Launch Control Center (LCC) takes control of the spacecraft after lift-off

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[33] Prepared by students of the "Creative Marketing Strategy" course, Harvard Business School, "Materials Processing in Space: A Marketing Strategy," June 1981.

[34] Communications Satellite Corp. Magazine, No. 1, 1980, pp. 26 and 33; No. 5, 1981, pp. 9 and 38.

and injection into the transfer orbit, oversees the insertion of the satellite into its proper orbital slot, and then performs the functional checkout. Following verification of proper operation, control of the satellite is then handed over to the owner/operator for further verification, testing, and ultimately, operations. The LCC was used for the first time with the launch of SBS-1 in November 1980.

Another area in which the private sector will certainly play an increasingly important role will be in the provision of postflight processing of the shuttle. Currently, NASA, using more than 25 individual contractors, is responsible for shuttle processing; it has, however, recently invited industry to bid on a contract to perform this function.[35] The company chosen would be responsible for refurbishment of orbiters after flight for subsequent missions, checkout and assembly of the solid rocket boosters, external tanks, and other shuttle elements, and for support operations and materials, including maintenance and facilities operations.

The transfer of shuttle processing to the private sector is an important step toward commercializing the entire space shuttle program. As has been mentioned many times before, industry is reluctant to invest in the shuttle, or any new space technology, because it cannot accurately assess the risks and the potential return. As industry becomes familiar with the shuttle, or other new space technologies, it will be in a better position to make the kind of financial assessments which must precede any major commercial investment.

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[35] Aviation Week and Space Technology, "Shuttle Contracts To Be Let to Industry," Nov. 2, 1981, p. 51; Aviation Week and Space Technology, "Processing Efficiencies of Shuttle Studied," Nov. 30, 1981, p. 18.

Chapter 9

INSTITUTIONAL CONSIDERATIONS

Contents

LIST OF TABLES

FIGURE

Chapter 9
INSTITUTIONAL CONSIDERATIONS

INTRODUCTION

National civilian space policy is implemented in a specific institutional framework, one which has evolved over the almost 25 years of U.S. space activity. (The evolution of that framework is described in app. A.) This framework is the **means** for accomplishing policy objectives, and it must be evaluated by how well it has done so and, more importantly, can be expected to do so in the future. Is the current institutional framework, which was largely established in the early years of the civilian space program, still appropriate, given the options for future national space policy? This chapter will examine this question and suggest the characteristics of alternate institutional frameworks for the U.S. space applications effort.

Policy

policy formulation includes, first, the identification and evaluation of alternative objectives and ways of achieving them, and second, the choice of a particular set of objectives and courses of action (i.e., policies). Policy implementation is the application of policies to achieve particular goals. Although policy choice and policy execution are closely intertwined, this chapter focuses on the **institutional framework for implementing policy,** not on the mechanisms for policy formulation and choice, which are discussed in chapter 10. What receives attention, rather, are the links between policy objectives and institutions, and the difficulties of establishing any one framework to meet significantly differing or changing objectives.

One qualification to this distinction is immediately necessary. If the activities of a particular institution are not tied to some set of externally determined needs or goals, then the internal needs and objectives of the institution itself—growth, maintenance, or, at a minimum, survival—can emerge as dominant influences on policy. The U.S. space program has not been immune to this tendency. For example, in 1969 the proposals for a future space program built around orbiting space stations and a space transportation system operating in the region between the Earth and the Moon, with an eventual goal of manned planetary exploration, emerged from within the National Aeronautics and Space Administration's **(NASA'S)** manned space flight organization, not in response to some externally imposed goal or objective.

overall, this assessment explicitly recognizes that the private sector can play an increasingly important role in space. The present chapter, in treating Government institutions and public policy mechanisms, provides some guidelines for determining the appropriate division between public and private sector roles in space, and it considers various methods and incentives to stimulate and support private sector activity, including potential mechanisms for Government/industry cooperation or collaboration in space applications.

In summary, this chapter analyzes issues related to alternative institutional frameworks for organizing the Government's share of the national civilian space applications program. It does not attempt to identify a single "best" framework; the choice of an institutional arrangement is a derivative issue, one dependent on answering the question, "Best for what?"

CURRENT INSTITUTIONAL FRAMEWORK

Before alternative institutions are examined, it is important to characterize the current structure within the Federal Government. The major Government actor for civilian programs is still NASA, although other Federal agencies are becoming increasingly involved in space. Table 20 lists the

Table 20.—Federal Agencies Active in the National Space Effort[n]

Agency	Budget for space activities (FY 1982 estimate in millions)	Significant space-related work
Department of Defense	$5,916.3	Communications, command and cent rol. Navigation, environmental forecasting. Surveillance R&D related to future military applications.
NASA	$5,617.3	R&D related to science and applications; transportation
Department of Commerce	$126.3	Environmental monitoring. Remote sensing (in 1983). Weather satellites.
Department of Energy	$38.0	Space nuclear power systems.
Department of Agriculture	$17.2	Crop assessment. Monitoring of soil, water, and vegetation.
Department of the Interior	$12.6	Surveillance and monitoring of natural resources. Mapping.

alt is not ~O~~ibla t. ~r~vlde a separate budget estimate for irltelllgence-related space activities, some of which are included in DOD figures.

SOURCE: Office of Management and Budget.

Government agencies with significant space-related activities.

Current NASA Structure

The institution with primary responsibility for the civilian space program is NASA, created in 1958 in response to Sputnik and mobilized in 1961 to achieve a goal of preeminence in all areas of space activity, particularly the development of the (large) technological systems required for the Apollo program. It is essential to emphasize that NASA was **not** designed to conduct routine operation of space systems that provide services to public and private users. Instead, operational responsibilities have been assigned ad hoc:

1. The National Oceanic and Atmospheric Administration's (NOAA's) National Environmental Satellite Services (formerly the Weather Bureau) operates meteorological satellites, while NASA continues to do relevant research and development (R&D); NOAA is also scheduled to assume management of the Landsat remote-sensing system in early 1983.
2. COMSAT was chartered to be the initial operator of communications satellites used for international traffic; later, the domestic communications satellite market was opened to any firm that could meet regulatory requirements.
3. NASA operates space launch systems as well as conducting R&D on space transportation.

NASA's internal structure has remained basically unchanged during the past two decades. NASA headquarters in Washington is responsible for overall management and technical direction of the various activities carried out by NASA field centers (many of which were inherited from the National Advisory Committee on Aeronautics), and outside contractors. it is also the focal point for relations with the Executive Office of the President, Congress, and other Federal agencies. The various NASA field centers are in charge of specific projects; most of the actual R&D work is performed by private contractors. The Federal Government initiates programs and projects, monitors technical performance of contractors, and (to date) has been the primary user of the spacecraft and launch systems incorporating the results of

R&D. Some 80 to 90 percent of NASA's annual budget goes to external grants and contracts; this pattern has remained relatively constant over the years. Though NASA has maintained a substantial in-house research capability, the bulk of its expenditures have gone to establish an extensive network of research organizations in industry, universities, and nonprofit organizations. Table 21 shows the past and present size of NASA and its support base.

The set of NASA field centers today is the same as it was during the early 1960's, except that a recent reorganization has led to a reduction in the number of centers reporting directly to NASA headquarters. Table 22 gives information on the current NASA field center structure. Because NASA is responsible for different kinds of space activities (as well as experimental aeronautical work), including science, applications, and development of technical capability, and because responsibility for each of those missions and its associated projects is rather closely tied to one or more field centers, one of NASA headquarters' major responsibilities is allocating priorities and resources. Decisions on policy and program priorities thus directly affect the associated field centers, and the current structure fosters competition among the centers within NASA's overall program. In this competition, for reasons to be examined, technology development and space science and exploration have traditionally been more successful than space applications.

NASA's institutional base constitutes an impressive national resource for space R&D. NASA's personnel, facilities, and contractor support base provide the means for carrying out challenging and significant efforts, as Apollo, the space shuttle, and Voyager (among many other accomplishments), have demonstrated. As Congress and the Nation consider future objectives for the U.S. space program, the resources NASA has already developed must be considered. If these resources are not used wisely and well, they will disperse and will be difficult to reassemble.

Department of Commerce Space Activities

The Department of Commerce's (DOC'S) involvement in space dates to 1961, when Congress directed DOC to establish and operate a meteorological satellite system to observe worldwide environmental conditions and to report, process, and apply data obtained by this system. This responsibility is now borne by NOAA. More specifically, NOAA's meteorological satellite programs are lodged in the National Earth Satellite Service (NESS) (until recently the National Environmental Satellite Service). I n November 1979, NOAA was also assigned responsibility for operating the U.S. land remote-sensing satellite systems, beginning with Landsat-D, in 1983.

Through the years NASA and NOAA have worked closely together to improve the Nation's ability to observe Earth from space: NASA conducts R&D, and NOAA operates the satellite systems once they have been proved. This relationship dates back to the initial TIROS weather satellites and will continue i n the Landsat program.

Table 21.—NASA and Its Contractor Base

Year	NASA budget in millions	Personnel at NASA headquarters	Personnel at NASA field centers[a]	Funds provided to NASA grantees and contractors, in millions: Industry	Funds provided to NASA grantees and contractors, in millions: University and nonprofit
1962	$1,825.3	1,641	26,938	$1,030	$50
1966	$5,175.0	2,152	35,903	$4,087	$178
1971	$3,312.6	1,894	31,805	$2,279	$162
1981	$5,537.2	1,658	25,755	$3,746	$361

[a] Jet propulsion Laborato is included, although formally it is part of the California Institute of Technology

SOURCE: National Aeronautics and SDace Administration.

Table 22.—NASA Institutional Structure

Name of center	FY 1980 R&D funding	FY 1980 research and program management funding	FY 1980 personnel complement
Headquarters (Washington, D. C.)	$ 133.8	$89.5	1,658
Johnson Space Center—manned flight (Houston, Tex.)	1,347.3	164.1	3,616
Ames Research Center (Mountain View, Calif.)	159.7	87.8	2,212
Goddard Space Flight Center—remote sensing (Greenbelt, Md.)	548.3	151.2	3,941
Kennedy Space Center—launch services (Cocoa Beach, Fla.)	277.1	133,2	2,291
Langley Research Center (Hampton, Va.)	169.8	114.0	3,094
Lewis Research Center—aeronautical research (Cleveland, Ohio)	168.1	94.8	2,901
Marshall Space Flight Center—space propulsion (Huntsville, Ala.)	846.8	155.9	3,646
National Space Technologies Laboratory (Bay St. Louis, Miss.)	9.2	4.9	111
Jet Propulsion Laboratory[a]-space science (Pasadena, Calif.)	276.5		—
	$3,936.6	$995.4	23,470

[a] JPL is federally funded but is operated by the California Institute Of Technology.

SOURCE: National Aeronautics and Space Administration, Office of Technology Assessment.

Satellites currently operated by NOAA/NESS include: 1) polar orbiting satellites with day and night global coverage and 2) geostationary satellites that provide continuous viewing of cloud and storm patterns in the Western Hemisphere. In addition, NOAA was to have been a participant, together with NASA and the Department of the Navy, in a proposed National Oceanic Satellite System; (NOSS) the project, however, has been indefinitely deferred.

NESS disseminates its data and products within a few hours of acquisition to a wide variety of users, the most prominent of which are the National Weather Service and the Department of Defense (DOD). The data are also recorded and archived by NOAA's Environmental Data and Information Services. The data from the geostationary satellites are distributed in real-time to seven satellite field services stations, which further distribute them to a number of users. Meteorological data from NOAA satellites are also widely disseminated and used by foreign countries.

NOAA integrates satellite-derived data with data derived from other sources in preparing weather forecasts and warnings about disturbances on the Sun, in space, in the upper atmosphere, and in the Earth's magnetic field; integrated data are used in various resource management tasks as well. In addition to using satellite-derived data for operations, NOAA conducts a variety of R&D programs which make use of these data or directly support its space-related activities.

Other DOC organizations involved in space-related activities include the Maritime Administration, which uses satellites to improve the efficiency of ship communication, navigation, and operations, and the National Telecommunications and

Information Administration, which is the Federal agency responsible for policy on the use of the frequency spectrum and geostationary orbit and for exploring new applications of telecommunications technology.

Other Federal Space Efforts

The largest Government space program, at least as measured by budget outlays, is conducted by DOD. This chapter focuses on civilian space activities; for a description of DOD programs, see chapter 6. The space programs of other agencies are as follows:

1. The Department of Energy (DOE) carries out technology development and production efforts for nuclear-powered electric generators to be used on long-duration spacecraft suitable for planetary missions. DOE has studied space systems to dispose of nuclear waste, and makes use of remote sensing data in support of its responsibilities to seek energy sources and to site facilities for nuclear waste disposal. and other energy-related needs.
2. The Department of the Interior (DOI) uses space-derived data in executing its responsibilities in resource management. The U.S. Geological Survey, part of DOI, manages the Earth Resources Observation Systems (EROS) program, which develops, demonstrates, and encourages applications of remotely sensed data acquired from both aircraft and spacecraft (see app. B on the Bureau of Land Management).
3. Other agencies of the Government, particularly the-Department of Agriculture, but also organizations such as the Environmental Protection Agency, make routine use of space-derived data (particularly from Landsat) in carrying out their missions. They do not, however, participate in space-related hardware development. The Department of Agriculture has been a major participant in such R&D efforts as LACIE (large area crop inventory experiment) and AgRISTARS, and integrates Earth observation data in its crop assessment and forecasting operations (see app. C on Foreign Agricultural Service),

DIFFERING GOALS, DIFFERING STRUCTURES

There is no single institutional framework that is "best" for the civilian space program. Rather, different national objectives in space can best be accomplished by different institutional structures; goals and the means to achieve them should be matched. The three scenarios below suggest the wide variety of institutional frameworks possible, and how they are related to various futures for the civilian space program:

- an expanded program, focusing either on a new goal comparable to Apollo or the shuttle, or on a variety of advanced applications projects;
- continuation of the status quo; and
- further reductions in the Government share of the civilian space program.

An Expanded National Space Program

One possibility for the national space effort is setting another Apollo-like goal, i.e., a large and challenging enterprise to be achieved on a pressing schedule. Several such enterprises have been suggested over the past few years; most involve the development of capabilities for routine manned operations in low-Earth orbit, now that the shuttle has made this location more accessible for a variety of purposes. Other proposed objectives include: 1) a large structure in geosynchronous orbit, and development of reusable transportation to GSO, and 2) solar power satellites. NASA's current leadership has endorsed the concept of some form of low-orbit, manned, space operations center as NASA's next major project, and congressional space committees have, in general, supported such proposals.[1] Like the shuttle, an orbiting operations center would be a **means** to carry out a variety of space applications and science missions, not an end in itself.

Such a high-technology development project would require the kind of engineering effort which current NASA development centers are best able to provide. NASA's present institutional structure is largely a product of the 1961 commitments to preeminence in space, particularly the Apollo program. One consideration is that the ability of NASA and its contractors to undertake a substantial engineering effort will erode without a commitment to such an enterprise. Scientific and engineering talent of the highest quality is in short supply in the United States. Given the current shortage of manpower available to support military and private sector space activities, NASA's personnel will be lured away to more challenging work elsewhere if NASA does not soon undertake a major new effort. Some have suggested that NASA and its technical and managerial capabilities should be mobilized for nonspace R&D projects, particularly in energy. Whether NASA's technical expertise, problem-solving approach, and institutional characteristics are relevant to meeting other national goals requires further analysis, and is outside the scope of this assessment.

Another scenario would be based on a judgment that the current and potential benefits of applying space technology justify increased Government investment in applications R&D, particularly in the face of international competition and foreign government support for applications programs. Included in this scenario would be Federal commitments: 1) to take the policy and institutional initiatives needed to move from development to operations in the public sector, and 2) to introduce innovative methods to bring the private sector into full partnership. There would be no overriding Apollo-like project to key the national effort; rather, the program would become more pluralistic. Several mission agencies and private firms could participate substantially.

Continuation of the Status Quo

Development and testing of the space shuttle have been the major components of NASA's budget over the past few years, and they are likely to dominate for the next three or four. Partly as a consequence, there have been few "new starts" in any program area—science, exploration, applications, or technology development. Continuation of this situation would reflect a policy decision that NASA's major role should be developing space transportation capabilities for other users, such as DOD, the private sector, and other civilian agencies. Activities in space science and applications would continue, but at relatively low levels.

The United States probably could not afford to maintain NASA's entire institutional base under this scenario. Although it may be in the national interest to maintain NASA's capacity to undertake a major technology program, NASA as it currently exists would eventually become outdated. Certain applications activities, and their associated centers, might be "spun-off" to the private sector or the military.

A Tightly Constrained Program

A variation of the preceding scenario with somewhat the same institutional implications is one in which no compelling rationale for a large-scale civilian space program gains acceptance. In this case, NASA's size, scope, and mission would be reduced to a continued but restricted investigation of potential space applications. Aggressive pursuit of other promising opportunities would be postponed until the potential payoffs can justify investment of substantial public resources. One possibility is the gradual retrenchment of NASA toward a research and early technology development organization with close links to the users of R&D. This restricted range of responsibilities would be similar to that of NASA's predecessor, the National Advisory Committee on Aeronautics (NACA).[2]

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[1] Administrator James Beggs has repeatedly made this point, and there is currently a top-level study underway within NASA related to future space station plans. See, for example, *Aviation Week and Space Technology,* July 27, 1981, pp. 23-25.

[2] For a discussion of NACA, see Arthur L. Levine, *The Future of U.S. Space Program (New* York: Praeger, 1975), ch. 2.

A key issue in all the above scenarios would be the division of roles and responsibilities between public and private sectors, and between NASA and other agencies within the Federal structure. There are two possible basic alternatives, and the remainder of this chapter provides criteria for evaluating them. These alternatives are:

1. NASA could become **the** civilian space agency, not just the space R&D agency. In addition to continuing to do R&D, NASA would operate space transportation services, the space segment and initial data processing for Earth observation systems (weather, land remote sensing, ocean remote sensing), public service communications satellites, and other space systems pro bono publico. NASA would also develop common "in-orbit infrastructure, " i.e., platforms, power supplies, communications and telemetry systems, construction and servicing capabilities, etc., which public and private organizations could use on a reimbursable basis. In this scheme, NASA would assist firms in transforming new space applications into profitable commercial ventures.
2. NASA could remain limited to an R&D role, and other Government agencies, such as NOAA, or private or quasi-private sector entities, such as COMSAT, would undertake various operational activities. NASA, in this option, could either: a) conduct an R&D applications program to advance technology without regard for its immediate commercial potential, b) concentrate on public good applications of space technology, leaving it to the private sector to invest in developing commercial applications, or c) focus on supporting public and private users. One issue related to this scenario is the allocation of responsibility for operating "space utilities" such as transportation, power, communications, construction facilities, etc.

In either alternative, more effective instruments would be required to link private and public sector users of space technology with NASA, the central R&D space agency. A tradition of collaboration between NASA as an R&D agency, operators of space systems, and the user communities has not yet developed, but is a necessity if this alternative is to be viable. NACA, NASA's predecessor, had a mixed public-private governing board representing all interests involved in aeronautics, both civilian and military. While not necessarily a relevant model for a "new NASA, " this pattern of developer-user linkage proved very successful in advancing the U.S. position in aeronautics.[3]

Much of the remainder of this chapter is a detailed analysis of the institutional issues involved in operating space technologies and in strengthening coordination between governmental and nongovernmental developers, operators, and users of space technology.

As the issues relating to commercialization are discussed in chapter 8, the following will concentrate on Government operations, though many of the issues involved are similar. For the purpose of this analysis, it is possible to separate the process of applying space technology into five distinct phases, each of which has different institutional implications. The following sections discuss generic institutional implications.

1. research and development;
2. demonstration;
3. transition to operational status;
4. operational status; and
5. support of operational systems, including continuing R&D in an applications area.

After this general discussion, and after analysis of the international institutional aspects of space applications in the next section, the last section discusses the institutional issues specific to each applications area,

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[3] Ibid.

INSTITUTIONS FOR SPACE APPLICATIONS R&D

NASA was assigned Government responsibility for civilian space R&D by the National Aeronautics and Space (NAS) Act of 1958. However the act was not specific about NASA's (or anyone else's) role in using or operating the results of that R&D. In space applications, almost by definition, R&D is conducted not as an end in itself but as a necessary step in reducing uncertainties and developing methods for the use of space systems to provide public or private benefits. Since applications are meant to be **used,** the key institutional question is how to create a productive relationship between performers of R&D and the ultimate users.

There are crucial differences between R&D conducted for systems to be operated by the Government and R&D for those to be operated by private firms. In particular, R&D for commercial applications must be influenced by considerations of eventual profitability.[4] However, there are also important common elements, particularly with respect to the relationship between user and developer. In the space sector, NASA has from the start (with the exception of launch services) been confined to R&D. This limitation, reinforced by the fact that NASA attracted in its early years engineers oriented towards advancing the frontiers of knowledge and technological capability, and the institutional culture derived from missions such as Apollo and planetary exploration, have certainly influenced NASA's applications efforts. NASA has developed an orientation towards "technology push" efforts. This orientation militates against being responsive to potential operators and users of space technology, who exercise "demand pull" on the directions of space applications development.

NASA, particularly in its early years, inevitably put more stress on advancing the technological frontier than on developing technology in response to user demands (which were virtually nonexistent) or in anticipation of the kinds of demands likely to arise. As the practical uses of the new technologies began to take shape, however, NASA continued to emphasize the development of more sophisticated applications technology rather than bringing adequate applications systems into early operation. This is in part a reflection of the reality that, once NASA completes R&D for an applications program, it must transfer it to some user outside of the agency. Consequently, the organization tends to hold on to programs, even if that means prolonging the R&D phase beyond the optimum point. The Landsat program, which many users have been treating as if it were already operational, is a case in point.

In recent years, NASA has put a higher priority on developing closer relationships with potential operators and users of space technology, particularly in remote sensing and advanced satellite communications. The management structure which had been adopted for the now-canceled NOSS gave NASA a central R&D role in bringing the demonstration system into being, but involved users, particularly from other Federal agencies, in management committees at three different levels of program operation. Figure 15 illustrates the NOSS management structure; it seems that a similar structure might be appropriate in other applications areas.

Such a structure links R&D managers with users and provides a setting for resolving differences in priorities, technical requirements, and budgetary commitments among involved participants. Few space applications R&D projects serve a single set of user requirements, and few will involve only NASA in their conduct. Thus a management structure for future application programs in which developers, operators, and users are linked from the start appears an improvement over past management practices in, for example, the Landsat program.

There is an unavoidable tension between the developers of a new technological capability and those who hope to use it. The most frequent failure in Federal R&D programs is inadequate attention to the realities and needs of eventual users in the planning and earliest research phases of

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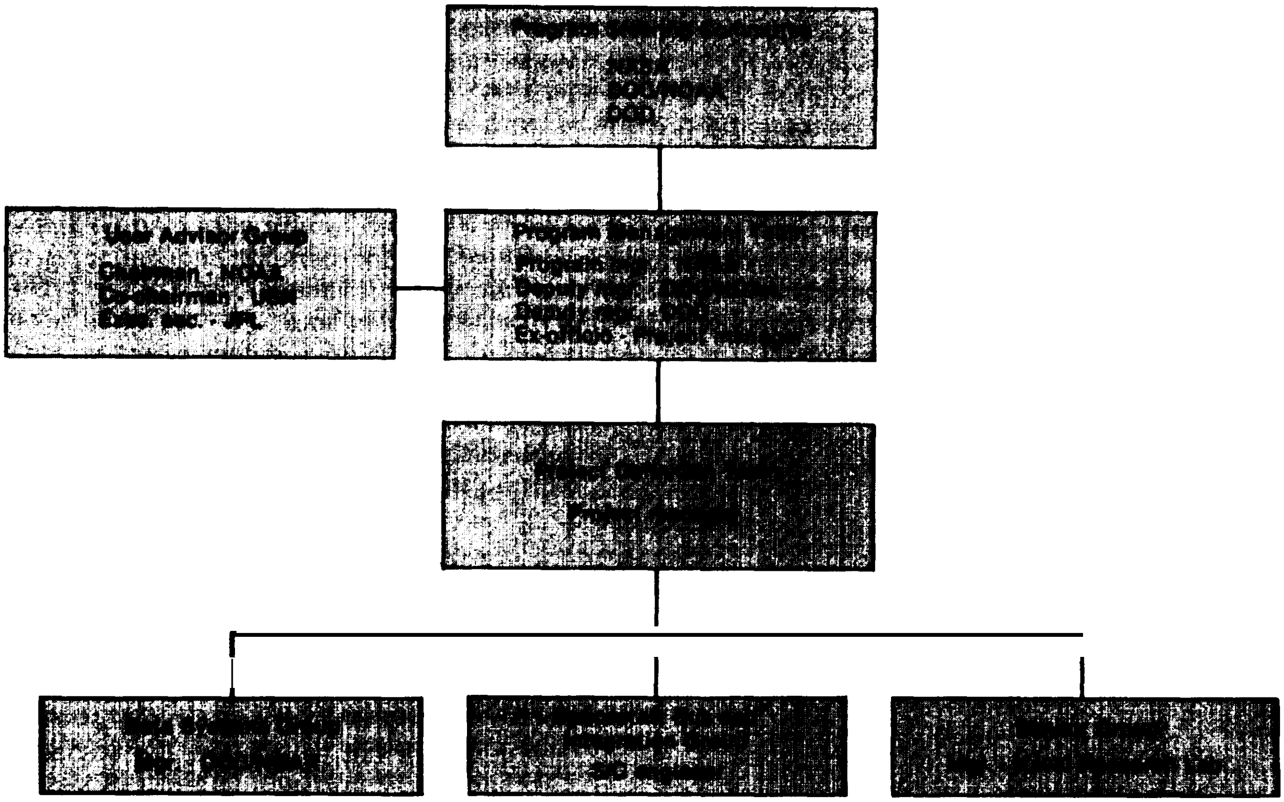
[4] This distinction is well-made in Peter House and David Jones, *Getting It Off the Shelf* (Boulder, Co.: Westview Press, 1977), chs. 3-5.

Figure 15.–Management Structure of NOSS



SOURCE: National Aeronautics and Space Administration.

a programs Engineers prefer to work in an environment where the only constraints are technological. In addition, the resources provided for planning an R&D project, as opposed to conducting it, are often inadequate. As R&D is being planned, users should participate in identifying specific applications, the environment in which they must operate, and the economic factors that will constrain an operational system. None of these factors has been given priority in NASA's applications programs until recently; rather, new technological opportunities have been the driving force in R&D planning.

Space activities are justified by a variety of rationales. But to the degree that space applications are justified by their potential benefits, there should be careful attention to the costs of operating a system. R&D serves in large part as a means of reducing uncertainty, but reducing cost and performance uncertainties may be just as crucial as reducing technical uncertainties. Certainly the benefit calculus will be different for public and private applications, since Government is not concerned with showing a profit. If a service can never be profitable, but society needs it, then it is Government that properly provides such a service. Even for public services, however, operating costs must be a continuing focus of concern throughout an R&D effort.

The LACIE program provides an example of such problems in the space applications area.[6] These problems can be avoided if developers work closely with users in guiding an R&D project.

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[5] Norman McEachron, et al., *Management of Federal R&D for* Commercialization, report from SRI International to Experimental Technology Incentives Program, Department of Commerce, 1978, p. IV-28.

[6] General Accounting Office, *Crop Forecasting by Satellite: Progress and Problems*, GAO Report, PSAD-78-52, Apr. 7, 1978.

If the R&D is in an area intended for eventual commercialization, then market analysis needs to be incorporated even at early stages in the R&D effort. The total range of users, their current patterns of operation, and the ways in which a new application might modify those patterns need to be identified. The likelihood that services or products can be produced at a cost acceptable to private purchasers needs to be estimated, and these estimates refined during the life history of the R&D effort. In this way, R&D intended for commercial application will be guided by private sector considerations from its inception.

In summary, then, the R&D phase of space applications activities needs to incorporate substantially more planning for eventual application than has been the case with NASA's past applications programs. Users must be significantly involved, without stultifying the creativity of researchers. Some means of resolving inconsistencies among user needs is required. Cost performance as well as technical performance must be borne in mind throughout the R&D process. In areas of new applications, the R&D project should be designed to give early and concrete evidence of specific benefits and the ways in which they will assist various classes of users. The kind of management structure which had been planned for the NOSS program might provide many of these features for public sector uses; commercial activities require market analysis and private sector involvement.

INSTITUTIONAL ISSUES AND DEMONSTRATION PROJECTS

The primary goal of an R&D program is to reduce uncertainties about the technical characteristics of an application opportunity. By contrast, a demonstration project is intended to illustrate the performance of a new technological capability in a realistic operating environment, in order to provide the information which potential operators need to bring that new technology on line. When an R&D program provides evidence that a new technology is likely to be commercially viable, potential private sector operators can undertake their own demonstration. But when the R&D program does not provide clear evidence, or when the benefits have a mixed public/private character, then the Government must subsidize at least part of the demonstration phase.

Failure to recognize and adjust to the differences between the R&D and demonstration stages is a likely source of difficulty in bringing new applications into being; it is very difficult to combine R&D and demonstration efforts in one undertaking.

It is possible to specify characteristics linked to the success of a demonstration project in providing the information to decide whether to take a new technology to operational status.[7] Those characteristics include:

1. ***A technology well in hand.*** Demonstration projects are not laboratories for resolving technological problems; rather, a successful demonstration project concentrates on providing information on the nontechnology-related characteristics of a new capability. Thus, demonstration projects should not be initiated prematurely, while major technological uncertainties remain.
2. ***Cost and risk sharing between developer and potential operator.*** If the demonstration project is a marketing tool to demonstrate to potential users the operating characteristics of a new technology, but these users are not included in planning or, where feasible, in sharing the costs and risks of the demonstration project, it is unlikely that the project will be responsive to the users' need for information.
3. ***Congruence with technology delivery system.*** In order to bring a new technology into

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[7] Walter Baer, Leland Johnson, and Edward Merrow, *Analysis of Federally-Funded Demonstration Projects,* report from Rand Corporation to Experimental Technology Incentives Program, Department of Commerce, 1976, p. v.

being there must exist some way to translate a technological possibility into an operating reality. The demonstration project should be organized to reflect the specific characteristics of such a "technology delivery system." When the technological capability does not match existing manufacturing or utilization patterns, particular care is needed to consider how those patterns might be affected.

4. ***Inclusion of all elements needed for operation.*** Successful demonstration projects should include in their planning and execution: potential operating organizations, potential users of a new technological capability, manufacturers of the systems in which the R&D result will be embedded, potential regulators, and other target audiences.
5. ***Absence of tight time constraints.*** Demonstration projects which face tight time and budget constraints are less likely to provide the necessary information needed for an operation decision.

The demonstration phase has proven to be a crucial step in translating R&D work into successful operating systems; experience in the defense sector ("fly before you buy"), for example, confirms this observation. The role of a separate demonstration phase is an area of both policy and program uncertainty in recent space applications efforts, and this uncertainty needs to be resolved in order to make the Federal R&D effort in applications more likely to pay off. In particular, NASA has not been able to secure the budgetary resources or political support required to conduct a demonstration, as defined here, of remote-sensing systems; rather, NASA has attempted to combine R&D and demonstration efforts in the Landsat program. Earlier communications satellites such as the Syncom project in the 1960's and the ATS applications technology satellite projects in the 1970's approximated some of the requirements of a successful demonstration project, although even in these cases R&D and demonstration goals were combined. Experience suggests that operators and users, whether private or public, are not willing to invest in a demonstration effort because of the particular characteristics of space activity, such as high front-end cost and technical uncertainties.

As is implied by the definition of demonstration project as concerned primarily with nontechnical aspects of a new technology, the design and execution of a successful demonstration project requires people trained in marketing, manufacturing processes, and other aspects of system operation in addition to individuals concerned with the technical aspects. Planning of a demonstration project should insure that these capabilities are included in the project teams. Demonstration projects managed and staffed by engineers alone are unlikely to be successful.

INSTITUTIONS FOR SPACE APPLICATIONS OPERATIONS

Properly speaking, the next topic should be the institutional issues related to making the transition from demonstration of a new application to its incorporation in operational systems. However, it makes little sense to discuss institutional alternatives for this transition phase without some prior discussion of "transition to what?" In addition, there are important differences between a space application operated by Government, and one in the private sector. Therefore, this section will discuss the institutional framework for making space applications technologies operational.

Private Benefits, Private Operators, Government Regulation

If the benefit to be delivered is primarily or purely private in character, such as point-to-point telephone or television relay, then private sector operators are the appropriate entities for that application. The Government role in this situation, once the transition from a Federal R&D program is complete, is regulatory in character.

Public Benefits, Public Operators

When a service has an overwhelmingly public-good character, it is often (though not always) the case that Government itself operates the system that provides that service. The social security program, the census, and military forces are examples of systems managed under public auspices. In the space applications area, meteorological data closely approximates a pure public good, and the national Government has not only developed but operated weather satellites through NOAA.

The major institutional issue related to Government operation of a space applications system is whether NASA or some other Government agency should operate space systems. The NAS Act has been interpreted to limit NASA to an R&D role, but reviews over the past decade have noted that it is possible, even without legislative revision, to assign more of an operational responsibility to NASA. Certainly, it would be possible to modify the 1958 act specifically to permit or mandate NASA to assume an operational responsibility.

The question of whether NASA or some other agency should operate Government-owned space systems depends on whether it is more desirable to link development and operation in a single organization, or to separate development from operation so that each organization has its own management structure. The major argument for separating development and operation is the likelihood that the conflicts between them will interfere with the ultimate objective of establishing the optimum applications system. The characteristics of a particular organization will determine whether user requirements or engineering desiderata predominate. Users tend to be conservative, to prefer only incremental changes from current practice, and to be driven more by consideration of cost and ease of operation than by the potential of a new technology. Alternatively, engineers tend to stress technological advancement and the development of new equipment, which may yield an impractical system.

New technological capabilities are, after all, only means to accomplishing some set of broader ends; in the organization of the Federal Government, most agencies are assigned a specific mission, rather than being organized around the means needed to provide the services they offer. According to this model, space application systems should not be managed by a “space” agency but by those who make ultimate use of the technology, i.e., the mission agencies. An example is NOAA’s operation of weather satellites, which are developed and built by NASA, according to NOAA specifications. NOAA in effect serves as a middleman between the developer, NASA, and the end users, domestic and international. A major problem arises when space systems, particularly remote sensing, serve a number of functions and a variety of users. This diversity makes it difficult to relate these applications to a single mission agency such as Commerce, interior, or Agriculture.

Arguments supporting a single organization for development and operations are to a large degree the converse of those just stated. R&D can best be made responsible to the requirements of both ultimate operators and users if a single chain of command deals with both phases of a project. Organizations with heavy investment in existing systems are likely to be unresponsive to new technologies and associated ways of doing business developed by “outsiders.” If a technology is transferred from one organization to another, difficult problems of changes in organizational loyalty, and disruption of prior relationships with suppliers, contractors, and users, are likely to occur. The management of applications systems on the basis of their technological character rather than the function they perform makes sense, it is argued, because of the multiplicity of users with different requirements, and because continuing R&D can be more effectively incorporated into existing systems if both are carried out in the same organizational structure.

The ideal framework for bringing a new application into operation is an effective and meaningful partnership between developing and using organizations. In some cases, particularly where the new technology provides a service that is not presently provided by established agencies, and where extensive technical and managerial expertise is required to operate the system, it is preferable to retain close ties between developer and operator. This is clearly the case for launch vehicles. In land remote sensing, too, it can be argued that NASA is the appropriate agency both to develop and to operate a Federal system, rather than transferring operations either to another Federal agency (i. e., NOAA) or to a private firm. (Commercialization of remote sensing would eliminate NASA's operational role.) Transferring responsibility to NOAA, as is presently being done, may not be desirable. For managing weather satellites, on the other hand, NOAA has the past experience, service orientation, and close ties to users required for effective operation. NASA can be of service by acting as "prime contractor" in meeting specifications set largely by the user agency.

Organizational Alternatives When the Benefits Are Mixed

When both Government and the private sector are major users of a new service, there is a **variety of institutional options. Which alternative is preferred depends on the characteristics of the application and of existing organizations, and on the likelihood that the new application will be integrated smoothly into the existing institutional framework. Thus, general guidelines are difficult to state.** The organizational alternatives in this situation are several. They include:

1. Government-owned and Government-operated system in which private users of the system purchase services or products from Government at a cost which is determined by Federal policy rather than market forces;
2. Government-owned, but contractor-operated system in which the Government uses a large portion of the system's products but where the contractor is also free, within some set of Federal restrictions, to offer service to nongovernmental users and to make a profit on those services;
3. single privately owned and operated system with guaranteed Government purchases and some protection from competition. The owners of such a system would have the responsibility for developing and servicing the private market for the system's products; and
4. privately owned and operated system or systems (depending on the demand) with open competition for sales to both public and private markets and with the prices of its product or service determined by market forces.

The criteria for selecting among these alternatives are specific to particular applications areas and thus are discussed in detail in section X11. In general, the Government-owned alternatives would be preferable if the Government were, at least for the foreseeable future, the dominant user, or if major noneconomic factors, such as foreign policy or national security concerns, constrained the use of the application. Private sector operation would be preferable when it offers greater efficiency, more flexibility, more effective linkages to various user communities, and where the economic incentives for a private operator are strong enough to ensure that the new application gets a fair test as an operational system, Any choice among these alternatives is likely to be controversial, and dependent in large part on political philosophy and the specifics of a particular situation.

A comparison of prior efforts to establish operational systems is important in analyzing institutional alternatives. (This comparison is limited to domestic entities at this point; section Xl contains analysis of the experience of international entities such as INTELSAT and INMARSAT.) In the space area, the most significant institution created so far has been COMSAT; this experience is analyzed in some detail in chapter 8. What is relevant here is to recognize that COMSAT was created for a combination of political as well as economic reasons. One strong motivation was to avoid granting a monopoly in international sateliite communications to AT&T. However, there was a recognition that satellite communications could be a private profit-making venture. Thus, the majority of Congress in 1962 thought it inappropriate to create a Government-owned entry in the communications business, and preferred to establish a private alternative. COMSAT originated out of a desire to move quickly to an international communication system based on satellites; it is only in the past decade that COMSAT General, a subsidiary of the basic COMSAT organization, has begun to seek domestic market opportunities in other areas of space applications. COMSAT General can be seen as a typical private sector firm seeking to maximizing return on its investor's funds, rather than an organization with its origin in Government policy.

There was substantial organizational innovation in establishing a private nuclear industry, and some of this experience may be relevant to space applications. A number of major facilities, requiring large amounts of capital investment, were created; an example is uranium enrichment plants. These multibillion-dol lar facilities were developed by the Government, and now are Government-owned, contractor-operated (GOCO) entities that sell enriched uranium to private nuclear operators while also providing fuel for the Government's atomic programs. In addition, a number of the major energy laboratories in the United States, such as Oak Ridge National Laboratory and Los Alamos Laboratory, are operated under Government contract by private entities as diverse as Union Carbide and the University of California. This kind of organizational flexibility in the energy sector may be appropriate in space applications as well.

A major argument for getting space applications operations away from Government- owned and operated structures is that the bureaucratic rigidities of the public sector are a major hindrance to systems which are servicing both public and private markets. In addition, the character of the civil service system, the need for annual or frequent authorizations and appropriations to cover operating expenses, and the desire to keep the direct Federal payroll as small as possible all lead to the frequent selection of a private sector operator to provide a service with mixed public/private characteristics.

Apparently, other countries find that the flexibility needed for developing markets for space applications is likely to be found outside of the formal government framework. For example, the European Space Agency has created a quasi-private entity called Arianespace to be the marketer and operator of space Iaunch services using the recently developed Ariane booster. There are 50 investors, ranging from major banks and aerospace firms to various European governments, particularly the French; formally, Arianespace is a French corporation. While Arianespace is charged with operating and marketing space launch services, the European Space Agency, an intergovernmental organization, remains in charge of further development of the Ariane launch system. The French are organizing a similar quasi-private organization called Spotimage to market the products of the French remote-sensing satellite SPOT. The major point is that the Europeans perceive that the competitive activities needed to make their launch vehicle and remote-sensing programs successful are better performed outside of government, though closely linked to government programs. It should be noted that both Arianespace and Spotimage will be heavily subsidized by their government sponsors; thus it will be very difficult to get an accurate evaluation of their economic viability. (For detailed discussion see ch. 7.)

TRANSITION FROM DEVELOPMENT TO OPERATIONS: INSTITUTIONAL ASPECTS

The transition from R&D to operations is perhaps the most difficult policy/institutional challenge for space applications. Understandably, both Congress and the executive branch wish to see immediate returns on the investment in space technology which the United States has made over the past two decades. Policy makers are aware of the extensive benefits predicted for space technology, and they exert pressure on the Federal space community to accelerate the delivery of those benefits. NASA, desiring to continue its applications R&D program, is strongly motivated to emphasize the great potential of space applications and to suggest that continued R&D is required to investigate current and future applications fully. The impression that space applications benefits are “just around the corner” is enhanced by the apparent (in retrospect) ease with which the transition from R&D to operations was made in satellite communications. The outlook for other technologies is more complex, however.

Communications satellites provided more efficient means of performing a well-established function. Once the advantages of communications satellites were demonstrated for a few countries already linked by other means of long distance communication, it was relatively straightforward to expand satellite communications to other countries and to other related activities. Other space applications, however, such as land remote sensing, are not substitutes for existing technological systems; rather they offer new opportunities for which established users and operational entities do not exist. Thus, a key to a successful transition is to identify and aggregate users; Government institutions to perform this task are not well developed.

Another important consideration is to initiate the operational system at a time when the user community is ready for it, not prematurely. A willingness to make investments with long-term paybacks and careful policy and program design is crucial to a successful transition from development to operations.

institutional issues are different when the operator is to be a Government agency or an entity operating under Government contract, and when the intended operator is a private-sector, profit-oriented organization. Each of these categories will be treated separately in the discussion which follows.

Transition to Government Operations

Ideally, the eventual operator would be identified when the R&D project aimed at investigating a particular application was initiated. In this way a partnership between the developer and the eventual operator could evolve throughout the project. The developer should pay careful attention to operator and user concerns such as cost, operating requirements, and reliability. An organization which is a candidate for operating a new applications system should have the technical capabilities needed to understand technological options, to assist in translating user and operational requirements into technical specifications, and to consult with R&D project managers as problems arise.

These desirable characteristics are more likely to emerge if the operating entity is identified early on; if development and operation were combined in a single organization, they would be more likely to be present. in addition, early identification of the eventual operator could minimize bureaucratic conflict over the assignment of responsibility for operations. Such has not been the case in past applications efforts, particularly in the remote-sensing area.

Though it would be desirable, in some respect, to designate the eventual operator at the outset of an applications R&D effort, it may not be possible to do so, particularly if the current policy of limiting NASA to an R&D role is maintained. The likelihood of choosing the appropriate operator is diminished when the application produces benefits of value to multiple users. In this situation, it is tempting to wait until the R&D project is further along to assign responsibilities for operations, in the hope that the appropriate operator will become more evident. The history of the remote-sensing program suggests the problems in deferring the designation of a lead agency (see app. A).

By identifying an operating agency early on, policy makers avoid the problem of having the transition plan developed totally within the development organization; such a transition plan is unlikely to reflect the concerns of a user-oriented organization.

Transition From Government R&D to Private Operation

An important issue in commercializing federally sponsored research is what Federal actions beyond R&D, if any, are required to make this transition. Several Federal incentives are discussed in chapters 8 and 10 of this report. The question regarding institutions centers around whether NASA, or any other Federal agency, currently has the authority or capabilities to provide such potentially desirable incentives. Though there has been substantial cooperation between NASA and the private sector, this has generally taken the form of a contract specified by NASA and bid on by private firms. The new Joint Endeavor Agreement is a significant move in developing new patterns of partnership aimed at encouraging private sector investment. The Federal Government, and particularly NASA, is still learning how to collaborate effectively with business in fostering commercial opportunities based on Government-developed technology in all sectors, not just space. This has happened slowly, given the traditional adversary relationship between public and private sectors.

There have been a number of suggestions for creating new Federal institutions to encourage space-based innovation; these include a new investment authority called a Space Bank or a more broadly chartered development organization called a Space Industrialization Corporation. The provision by Government of investment capital or other substantial forms of quasi-commercial support would represent a significant departure from past Federal actions. Although other countries (most notably Japan and some European countries) have provided this kind of support to their private sectors, it seems likely that given the strong U.S. tradition of separating the public and private sectors, and the current trend towards restricting the Federal Government, that there would be strong opposition to creating new Government institutions of this sort. On the other hand, concern for declining American industrial productivity and the increasing threat of foreign competition in advanced technology areas could make such innovations politically attractive.

In bringing the first commercial application of space technology, communications satellites, into being, the Federal Government did take a substantial institutional initiative in creating a semiprivate designated entity, COMSAT, to manage the satellite system. An important issue is whether similar kinds of institutional innovations are required in other applications areas. This question is addressed later in this chapter, particularly in the following section, which deals with providing broad-based infrastructure to support space applications.

INSTITUTIONS FOR SUPPORTING SPACE OPERATIONS

An important institutional question concerns the provision of routine support operations for public and private industrial activities in space. Such operations would include reliable and affordable transportation from the surface of the Earth to low-Earth orbit, and between low-Earth orbit and other desired orbital locations; construction and maintenance of orbital platforms; and providing in-orbit power and communications. it is possible to conceive of some form of "space utility" providing these common services to a variety of users, not only industrial but also scientific and perhaps military.

Should such space utilities be operated by a private or public entity? Almost certainly, given the multiple users of in-orbit facilities and of space transportation, it will be Government that provides the initial investments to develop these capabilities. NASA's plans for a space platform or operations center are driven by the eventual need for routine in-orbit capabilities such as those just discussed.

The period during which this kind of "infrastructure" for supporting space operations will be required is a decade or more in the future. Thus, it is somewhat premature to carry out a detailed analysis of institutional alternatives. However, many of these issues will arise in the course of arriving at an institutional framework for operating the space shuttle, and the approach taken to shuttle operations is likely to set a precedent for other forms of support services. Thus, the following analysis of institutional options for shuttle operations is also relevant to other support systems for space.

There are essentially two ways an operational space transportation service using the space shuttle might be organized. One is to create a designated private firm, or use an existing firm or consortium, to own and operate space transportation services for all users (with the possible exception of the military and intelligence services). The second is to have the Government operate the shuttle fleet and sell launch services on a reimbursable basis to private sector users, as is the current practice with expendable launch systems. Of course, either alternative could face competition in providing launch services from a U.S. private organization or Arianespace.

While routine launches of payloads into near-Earth or high-Earth orbit now seems like an exceedingly complex and risky undertaking, there is no technological reason why these services could not be provided by a private operator with sufficient resources and experience. The current shuttle development and demonstration program will provide information on costs and experience with operating characteristics, allowing potential private operators to evaluate the possibility of profitable commercial operation. NASA is currently contracting out large segments of shuttle management and maintenance to private firms, and recently invited aerospace companies and airlines to bid on the provision of a complete package of services for processing the shuttle for launch.

The argument that a Government entity should provide space transportation services is based on several beliefs. One is that the use of launch vehicles for military and intelligence missions makes it desirable to keep launch technology under Government control. Others are that the principal user of launch services in the foreseeable future will continue to be Government, and that no private sector firm without extensive Government subsidy would be able to provide the launch services Government will require. Another is that further Federal development of space launch capability is desirable and R&D toward this capability should be carried out in close conjunction with current operations in space transportation.

Private ownership and operation of space systems would give rise to a need for Federal oversight and regulation. For a discussion of the issues involved, see chapter 8.

Another option for providing space transportation services or orbital support services is international ownership and management of a space utility or a common space platform. The analysis below of international dimensions of space applications raises this subject briefly.

SPACE APPLICATIONS IN AN INTERNATIONAL CONTEXT: INSTITUTIONAL ASPECTS

international cooperation in sharing data from meteorological systems and in operating international and communications satellites has proved successful for almost two decades, and thus it is not surprising that other space applications are frequently suggested as candidates for some form of internationalization. A touchstone for any analysis of such suggestions is the successful experience of the International Telecommunications Satellite Organization (I NTELSAT). The United States took the lead in 1964 in helping to found a multinational entity for using communications satellites for video and voice transmissions among various countries; the original 19 signatories of the INTELSAT interim agreement have grown to 106 owners of a unique international organization. The most striking feature of INTELSAT is that it combines policy management by government representatives (for the most part) with the operation of a successful commercial enterprise returning 14 percent annually on its owner's investment. Thus, INTELSAT provides a seductive model for other areas of space applications. The question is whether this kind of international organization can, or should, be duplicated in other applications areas.

A brief review of various applications areas suggests the limitations of the INTELSAT model. Certainly materials processing is in much too early a stage of development to consider any permanent institutional arrangements, much less a possible multinational one. This is particularly so since the most likely path for developing materials processing applications is through private enterprises. Space transportation at this point is an area of international competition, not collaboration, and there is no indication that the current developers of space launch systems will want to operate them as anything but national public or private enterprises. There are some potential new international dimensions to advanced communications satellites, such as navigation and search and rescue systems, but in general, most advances in communications satellites are likely to be incorporated in INTELSAT or INMARSAT. It is only in remote sensing that the issue of international institutions is currently relevant, and most of this section devotes its attention to this issue. There is also some discussion of the potential for internationalizing space support services, particularly large orbital platforms in low or geosynchronous orbit.

it has been the policy of the United States since 1969 to make the benefits of the U.S. remote-sensing program available to all peoples of the world. At issue now is how best to implement that policy: through a U.S.-owned and operated system which makes its own arrangements for international participation, or through some form of internationally owned and operated system in which ownership is proportional to investment and/or usage.

The institutional choice is between some form of international consortium, a la INTELSAT, or continuation and expansion of the current U.S. national system. A variation of this latter alternative would be if the U.S. system were privately owned and operated, since foreign governments have a number of concerns related to private control over remote-sensing operations. Any private sector operator of remote-sensing systems would have to operate, with respect to non-U.S. imaging, under a specific set of Government policy guidelines.

The most important benefit from a successful international remote-sensing system may well be political, rather than technical or economic. An international system could allow participating countries to have a say in system management; this feature would be especially attractive to a nation that receives substantial benefits from remote sensing but cannot afford to carry out such activities by itself. Other benefits to the United States of an internationally owned and operated system would include some degree of cost sharing, some ability to limit the development of other national systems and the resultant competition for remote-sensing markets, and less suspicion that the United States was appropriating information for its own purposes, It is also likely that limits on resolution could be more easily agreed on if there were a single international system rather than competing national systems. Finally, effective international cooperation for the common good is desirable in itself, transcending the direct benefits to be achieved from remote-sensing technology.

Creating this kind of international institution for remote-sensing operations would not be straightforward. It is sometimes forgotten that it took from 1964, when the interim INTELSAT agreement was concluded, to 1971, when the definitive INTELSAT agreements were signed, to make the transition from a U.S.-dominated communications satellite system to a more equitable arrangement.

Because there are conflicting national interests related to remote sensing activities, and because there are private sector as well as public sector concerns involved, negotiations preceding the founding of an international institution would of necessity be lengthy. In addition, the kinds of problems which have arisen at the domestic level in the process of establishing an operational structure for remote sensing are likely to be repeated at the international level. For example, organizations as diverse as the Food and Agriculture Organization, the World Meteorological Organization, and other, more politically motivated, U.N. organizations are likely to make a claim for some share in the control of any new international organization for remote sensing.

The history of INTELSAT also suggests that the ability of the United States to influence the direction and policies of a similar organization for remote sensing would diminish over time, as the organization itself matured. In addition, if the new international organization is successful the economic benefits will flow not only to the United States but to other countries owning and using the system; the U.S. aerospace industry could lose its dominant position in remote-sensing technology as the institution awards contracts on the basis of international competition. On the other hand, competition for U.S. systems will arise even in the absence of any INTELSAT-type organization; such an institution could serve to regulate or forestall the establishment of competitive systems such as SPOT. Here again, the INTELSAT experience is relevant; INTELSAT contracts have been important in the development of non-U.S. communications satellite technology and launch system capabilities.

Unlike COMSAT, which is essentially a private sector organization, most nation-states' representatives in INTELSAT are publicly owned communications organizations. Thus, INTELSAT demonstrates that it is possible to combine privately and publicly owned organizations in the same institutional framework. However, a number of issues related to remote sensing did not arise in the case of communications. In particular, if an international entity were initially based on a U.S. system owned and operated by a private firm, it is not clear how the current policy of open access to data could be maintained, while at the same time the economic interests of the private entity were protected. There are clearly tensions between the current policy goal of commercializing U.S. remote-sensing operations and the preceding argument that international institutions might well operate a remote-sensing system.

Previously there was discussion of a possible space utility to provide common services required by a variety of operations in space. This space utility would be an international entity, where investment and ownership would be distributed among a set of regional, allied, or global partners. Although internationalization of an emerging space operations utility is not fully explored here, this possibility deserves continued attention as application programs and their supporting infrastructure mature.

INSTITUTIONAL ASPECTS OF SPECIFIC APPLICATIONS

The discussion of generic institutional issues previously discussed provides a basis for identifying institutional concerns for each of the application areas treated in this assessment and for suggesting ways to deal with these concerns. Each application area—communications, remote sensing, materials processing, and transportation-is examined below from this perspective.

Communications

The primary issue in communications satellites is not institutional. As has been discussed in chapters 3 and 8, NASA's major thrust in this area is a proposed research, development, and demonstration effort in the 30/20 GHz range. This assessment has suggested that it may not be necessary for the Government to provide most of the funding for the flight demonstration of a satellite embodying this technology; the private sector could use the results of related R&D conducted under the sponsorship of national security agencies as a starting place to mount a demonstration effort funded primarily from its own resources.

If, however, a decision to continue a NASA communications R&D effort in the 30/20 GHz region were made, then this program should be conducted in close cooperation with both satellite manufacturers and communications satellite users. In both its R&D and its demonstration phases, this program might be amenable to institutional experiments such as public-private cost-sharing and risk-sharing and to joint planning and management structures. It may be possible to move quickly to a demonstration of a 30/20 GHz system, but care should be taken not to undertake such a demonstration if R&D is not essentially complete. As has been discussed earlier in this chapter, attempting to combine the R&D and demonstration phases is not usually a successful approach.

If the proposed NASA 30/20 GHz RD&D program is initiated, and if it is planned and managed according to the principles discussed previously, then no additional Federal actions should be required in order to make the transition from R&D to operations. If this new capability proves to be technically and economically viable, private firms will incorporate it in planning them for the next generation of communications satellites.

Remote Sensing

Many of the problems related to the Nation's R&D program in land remote sensing result from the different perspectives of developers and users. NASA views this effort as one of developing a new and experimental capability; the various users see the results of the program as immediately beneficial and have attempted to treat the system as if it were already operational. NASA has been caught between carrying out its R&D mission and responding to users who want to make immediate operational use of the Landsat system. To date, users of the remote-sensing system have not participated significantly in decisions regarding its status and future. The transfer of Landsat management to NOAA is designed to alleviate this shortcoming.

The division of responsibilities between any future R&D program in remote sensing and the operations of a working land remote-sensing system will have to be negotiated. If, as is suggested below, NASA is assigned the operational role, this issue becomes less problematic. If the operator is another Government agency, or a private firm, it may be desirable for NASA to perform some or all of continuing R&D.

Though Landsat has succeeded in providing the information needed to understand the kinds of public and private benefits that can be gained from remote-sensing technology, it has not been able to provide sufficient information on costs and on the potential market for remote-sensing data. Again, this is largely because the program has been run as an R&D, rather than a demonstration, effort. One heritage of the "Apollo-era" NASA is a desire to control most or all of a system development process, emphasizing its research and engineering aspects, rather than to share control with other entities, including other Federal agencies. This tendency has been noted for the initial Landsat and Seasat programs, and it seems characteristic of the Landsat-D effort as well. Landsat-D involves the first use in orbit of an advanced sensor called the thematic mapper, the characteristics of which are not well enough known to consider it an operational system.

The prospects for successfully achieving the quite different objectives of a NASA R&D program and a NOAA demonstration program within this single flight effort seem limited. Most of the principles for a successful demonstration effort presented previously have been violated in putting together the plans for Landsat-D. Users have not been closely involved in planning the program; there is a poor match between the characteristics of the advanced sensors to be flown on Landsat-D and the needs of the existing or potential user community for remote-sensing data; and a fair degree of tension exists between NASA and NOAA on account of their differing objectives for the program. In addition, technical problems with the thematic mapper have made the effort even more of a development rather than demonstration undertaking.

Undoubtedly there is a tradeoff between separating the development and demonstration phases, and the high cost of flying a fully qualified space system at least twice, but the increased assurance of accomplishing program objectives makes such an investment worthwhile. The Landsat program has not been planned with a clear understanding of the requirements of bringing an innovative new technology into operation. In addition to the problems of incorporating a new way of doing things into existing patterns, Landsat has exacerbated rather than minimized institutional conflicts and differences of perspective affecting operator and user acceptance of the new technology.

It is probably too late to remedy some of the basic flaws in the design of the Landsat effort. Rather, there should be an attempt to recognize the institutional, funding, and programmatic constraints under which the Landsat-D effort now operates, and to determine whether those constraints can be modified in order to reflect a more balanced approach to development and demonstration of a new technology. The issue of the institutional framework for an operational remote-sensing system has been controversial for almost a decade now. There has been extensive analysis both by the executive branch and by Congress; the full range of that analysis will not be reviewed here. This discussion will be limited to applying general principles provided previously to current proposals for operational remote-sensing systems.

The key policy issue in choosing an institutional framework is whether the benefits derived from remote sensing are primarily public or private; the available evidence suggests that they are a mixture of both. Because Landsat has been run as an R&D program, and because the prices of Landsat data have been heavily subsidized, the market for data from an operational but more expensive system is not well defined.

The process of moving remote sensing from R&D to commercial operations has been underway for 3 years now. The current transition planning has been plagued by external and internal difficulties. NOAA, the Government agency responsible for the transition, has not been given the resources to acquire the technical and economic capabilities needed to deal effectively with NASA, the present operator, or with eventual operators and users, public and private. The lack of budgetary and institutional commitment to the commercialization of remote sensing has prevented potential private sector operators from taking the Government's efforts very seriously.

Recently, COMSAT General proposed to assume ownership and operation of NOAA's meteorological and remote-sensing satellites.[8] The prospects for such takeover depend on the balance between public and private markets for Earth observation data. Certainly the established market for meteorological data is governmental in character, and presumably the Government would contract to buy those data from the privately operated system and to make it available as a public good, if the COMSAT proposal were adopted. There is also a large public sector market for remote-sensing data at the Federal, State, local, and international level, and presumably the Federal Government would also purchase the data needed to serve the public market from COMSAT. If these two public markets turn out to form an overwhelming share of the total demand for Earth observation data, then the COMSAT proposal should be approved if it would provide significant efficiencies in operating performance and cost. An alternative to the COMSAT proposal would be that a Government agency operate remote-sensing systems and make their outputs available to the private sector at a cost reflecting, for example, the marginal cost of obtaining and reproducing the data or some attempt to recoup system development expenses,

If, however, the Government market for meteorological and/or remote-sensing data were relatively soon to become a minor share of the total demand, then the COMSAT proposal would be better understood as an innovative and aggressive institutional initiative on the part of a private firm,

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[8] Klaus Heiss, "New Economic Structures for Space in the Eighties," *Astronautics and Aeronautics,* January 1981, pp. 19-21.

whose risks are minimized by guaranteed public purchases, but not totally eliminated. A major issue would be whether the Government should attempt to recoup any of the R&D and system development costs that made a private venture in remote sensing possible. The alternative is to view the sunk costs as an appropriate Federal stimulus to private sector activity. Access to remote-sensing products by non-U.S. users would be another area of concern. Provision would have to be made to ensure that private, profit-oriented operation (whether by COMSAT or in some other form) is compatible with the current U.S. policy of unrestricted access to all available data. In addition, a national remote-sensing system which is privately operated may not be compatible with eventual internationalization of remote-sensing efforts.

If the current policy of early commercialization of remote sensing were modified or reversed, it might be preferable to have either NOAA or NASA operate remote-sensing systems. The analysis in this chapter suggests that NASA would be a better choice than NOAA as an operating agency, since remote-sensing technology is still evolving rapidly and the existing relationships between the users and NASA form a basis for continuation and expansion.

Materials Processing

The research effort that might lead to widespread use of space for processing or manufacturing is still in its early stages. Much more basic and applied science is required before a wide range of specific applications can be tested. Thus the materials processing program provides the best opportunity within the current program of space applications R&D for applying the principles identified above. Materials processing in space is an example of a technological opportunity where the conditions which call for Federal involvement exist—high risk, high cost, long time to pay back. It is clear that materials processing makes sense only as a commercial activity, and thus any federally funded R&D should be planned with considerations of market and cost in mind. Innovative policy instruments such as the joint Endeavor Agreement (discussed in ch. 8) may be appropriate ways of accomplishing this. What is crucial is designing the materials processing R&D effort in ways that consider the likely future operating environment of commercial activities, rather than exploring exciting technological possibilities, while paying no attention to the commercial potential.

The demonstration phase for most kinds of materials processing activity is still some years in the future. However, the McDonnell Douglas/ Ortho Pharmaceutical joint venture experiment is planning for a flight demonstration in the mid-l *980's.* The basic technology will be tested in orbit first; if successful, a separate effort will to demonstrate that technology in an operating environment.

This approach to developing and demonstrating materials processing capabilities seems appropriate for other projects as well. Given that materials processing must ultimately be commercialized in order to be successful, there should be continuing strong, emphasis on the involvement of private industy in MPS activity, especially as the transition from R&D to the demonstration phase is planned. The kind of risk- and cost-sharing that currently characterizes the joint Endeavor Agreement (and is discussed above for demonstration efforts in the communications satellite area) should also characterize any further demonstration of materials processing technology.

A great deal of attention has been given to the general question of possible Government initiatives to stimulate the transition from the demonstration phase to private operations. Two sets of congressional hearings have been held, and a proposal to establish a Space Industrialization Corporation, as a source of investment and other policy stimuli, has received extensive analysis.g While this attention to transition planning for materials processing is laudable, the relatively early stage of the materials processing program suggests that it would be premature to select any particular form of government subsidy for the post-demonstration transition phase. Much more

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[9] House of Representatives, Committee on Science and Technology, hearings on Space Industrialization Act, 1979 and 1980.

needs to be learned from the experience of, for example, the joint endeavor experiment before an efficient and equitable mode of Government-industry cooperation can be identified for materials processing or other new space technologies.

Transportation

Continuing improvement and upgrading of the space shuttle and development of a truly reusable orbit-to-orbit transfer stage appear to be crucial elements of the Federal R&D effort in space transportation. Given its strong institutional capabilities in space propulsion and vehicle design, NASA is the appropriate focus for further R&D in this field. Essential to an R&D effort that serves space transportation users will be stability and predictability, so that users can expect to have new launch capabilities available on schedule and at predictable prices.

The initial flights of the space shuttle are billed, correctly, as development rather than demonstration efforts. However, there is no separate demonstration phase as part of the STS program; after the initial four flights, the system will be declared operational and begin to fly payloads regularly. In reality, demonstration of the operating characteristics of the space transportation system, and particularly those of the shuttle, will come over time as the costs of each incremental shuttle flight, and the potentials and constraints of the shuttle as a launch system become better known. It should be recognized, therefore, that the actual demonstration phase of the shuttle program is likely to extend beyond 1985, and the information needed for private-sector operators to make an accurate assessment of the potential returns from shuttle operations is unlikely to result from the early years of the shuttle effort.

The transition to an operational system will require that, whoever the eventual operator may be, policies with respect to patent and proprietary information protection, launch assurances, Government preemption rights, and costs must be developed. A variety of institutions will have to evolve, especially those for marketing, insuring, and financing operational launches. The competition from potential privately developed expendable launch systems with lower performance but also lower costs than the shuttle may play an important role in future private sector operations. The transition phase is particularly complicated by the mixture of military, intelligence, and civilian Government requirements, together with private sector requirements for space transportation services. Institutions for resolving these conflicting demands will be required.

Providing routine space transportation services is different from operating the three applications discussed above: transportation services support operations in space, rather than being integral to a particular applications system. The issues related to the operational form for space transportation services have been discussed previously.

Chapter 10

POLICY ALTERNATIVES AND THEIR ASSESSMENT

Contents

FIGURE

Chapter 10

POLICY ALTERNATIVES AND THEIR ASSESSMENT

INTRODUCTION

This chapter brings together the background, technologies, and specific issues that are needed to formulate and analyze policy options. It establishes a range of policies that maybe considered in the light of the analysis in the earlier chapters of this report and current congressional practice and suggests a specific policy formulation. It also assesses the policy options with respect to their potential effect on existing and future programs.

Frequently, "space policy" is confused with "space program, " and a review of "space policy" might be expected to provide recommendations for new projects. As understood in this assessment, space policy is the set of guidelines which establishes the goals and the institutional framework for the civilian space applications program and broadly defines its implementation. This definition of space policy includes the types of measures that are within the domain of legislative action. Specific program elements or space systems are not, strictly speaking, "policy" and are only treated to illustrate the options discussed.

POLICY GUIDANCE: CATEGORIES AND CRITERIA

A number of general categories and criteria guide the process of formulating policy. This section summarizes some of the policies that now exist and from them develops the categories and criteria to be employed in selecting possible future policy options.

National Aeronautics and Space Act (NAS Act)[1]

The principal guidance may be derived from the 1958 NAS Act, the existing legislative authority for the civilian space program, where there is a declaration of policy and purpose and where the functions assigned to the National Aeronautics and Space Administration (NASA) are specified. This legislation sets forth the following general categories of policy guidance:

- ***Guiding principles or philosophy.—Such*** phrases as " . . . peaceful purposes for the benefit of all mankind" and " . . . a civilian agency exercising control over aeronautical and space activities sponsored by the United States, except . . . defense . . . " provide broad philosophical guidelines for the conduct of the national space program.
- ***Goals or objectives.*** —The specific areas defined in the NAS Act include a very general guide to the scope of the U.S. space program, e.g., "expansion of human knowledge . . . ," "improvement of . . . aeronautical and space vehicles," "development and operation of vehicles capable of carrying instruments . . . and living organisms through space," "long-range studies of the potential benefits of . . . aeronautical and space activities," "preservation of the role of the United States as a leader . . . ," "making available to agencies . . . concerned with defense . . . discoveries (by NASA, and vice versa)," "cooperation . . . with other nations, " "ground propulsion systems R& D," " . . . development of advanced automobile propulsion systems, " and " . . . research . . . to alleviate and minimize the effects of disability. "
- ***Organization.–The*** act specified formation of a new agency, NASA, and a new coordinating body, the National Aeronautics and Space Council (which no longer exists–see ch. 3 and 9). It did not specify the internal organization of NASA, but did name the members of the Council. Several executive level positions were specified for NASA, including an Administrator, a Deputy Ad-

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[1] *National Aeronautics and Space Act of 1958,* **as amended, and related legislation. Public Law 85-568 (see app. i).**

ministrator, and seven Associate Administrators.

- Functions.—Both the Space Council and NASA were given specific functional responsibilities. The Council was charged with: developing a comprehensive program of aeronautical and space activities; responsibility for the direction of major aeronautical and space activities; providing for cooperation between agencies; and resolving differences on aeronautical and space matters. In addition, the act specified that NASA would plan, direct and conduct aeronautical and space activities, use the scientific community, disseminate widely the knowledge it gained, and conduct R&D in specific areas.
- ***Budgets or resources.*** —An annual authorization and appropriations process was required, with no special multiyear features for longer term programs and no guidance about appropriate levels of support.

COMSAT Act and Related Legislation

The “Communications Satellite Act of 1962” (Public Law 87-624)[2] was an innovative policy step that recognized the rapidly growing potential of space platforms for communications services as well as the need to clarify the institutional setting for providing these services. it created a new, for-profit corporation, the Communications Satellite Corporation (COMSAT), to act for the United States in establishing an international, ***commercial,*** communications satellite system. It also clearly affirmed that NASA would cooperate with COMSAT in research and development (R&D) and provide reimbursable launch and associated services.

The intent of the legislation, inter alia, was to move rapidly toward establishing such a system and to remove some of the ambiguities and uncertainties about the possible role of other firms, especially AT&T, that could have entered the international satellite communications picture. There was a clear intent to have a single global system. This was largely for technical reasons: at the time the most likely system involved large numbers of medium-altitude satellites that, as they moved in their orbits, would periodically enter and leave the fields of view of the many ground antennas sending and receiving signals through the system. The difficulties of managing multiple systems, each involving many moving satellite repeaters and the consequent high probability of overlapping and interfering signals, made a single system appear a necessity. However, experiments with synchronous-orbit platforms soon demonstrated the desirability of using high-altitude repeaters for the system, making multiple systems technically more feasible. There were also strong political reasons to favor a single multinational system dominated by the United States. In addition, the financial and managerial efficiencies of a single system were significant. Hence, the momentum for a single global system was sufficient to preserve the initial international organization that was established, INTELSAT, and more recently, to extend the concept to marine communications via a similar structure, INMARSAT.[3] Congress again acted to designate COMSAT to act as the U.S. participant in the INMARSAT system.

Other Legislative Measures

When the NAS Act was enacted in 1958, the nature and scope of the Nation’s future space activities were only dimly visible. In more recent legislation, such as in the energy field (where the technologies are better known and Congress is very familiar with the institutions), the relevant legislation has been significantly more detailed and broader in scope. While the wisdom of a detailed specification of internal agency structure and specific programs is open to considerable debate, this recent practice suggests that similar measures may properly be considered in this analysis. For example:

- ***Technology-specific goals or objectives. — In*** the energy field, Congress has mandated that certain particular technologies be developed:[4] electric vehicles, ocean thermal

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[2] *Communications Satellite Act of 1962,* Public Law 87-624, 87th Cong., H.R. 11040, Aug. 31, 1962.

[3] *Communications Satellite Act of 1%2,* Amendment: *International Maritime Satellite Communications Act, Title V,* Public Law 95-564, approved Nov. 1, 1978.

[4] Examples include: *Solar Energy Research, Development and Demonstration Act of 1974,* Public Law 93-473, Oct. 26, 1974; *Geo-*

electric Conversion (OTEC) systems, photovoltaic systems, and magnetic-confinement fusion (using Tokamak devices). A comparable action in the space field might be to specify the development of a solar-electric propulsion system or a synchronous-orbit storm warning system. These examples of congressional "policy" setting come very close to being program definitions. At the beginning of this chapter, it was stated that such program definition would not be considered except as part of a larger policy framework. It must be recognized, however, that there may often be pressures to include specific technological directions in new space policy measures, and that such action is not inconsistent with the pattern set in other high-technology areas. At the very least, it is essential to consider the policy implications of mandating particular projects, including the effects on institutional structures, public-private relations, and the balance between scientific and applications programs.

- ***Tax and other incentives; loan guarantees.*** – Among the policy tools that have been used to achieve specific goals by affecting the behavior of individuals and private firms, the economic incentive has been the most typical. Such incentives have been enacted by various methods: 1) by adding a tax levy to discourage, or reducing a tax to encourage, specific activities; 2) through direct subsidy (e.g., food stamps); or 3) through loans and loan guarantees (to students, homebuyers, etc.). A recent example of this practice in the energy area combined all three of these incentives in the Windfall Profits/Synfuels Corp. packages

  One additional example of an economic incentive deserves further mention—i. e., a guaranteed price for delivery of a product at some future time. In some instances, where there are several potential strategies for producing a desirable product, a policy option is for the Government to guarantee to purchase a given quantity of the product at a set price, high enough to provide an attractive rate of return to the risk-taker. In such a case, the private supplier is responsible for detailed management of the project, for the technical choices that are made, and for the ultimate delivery of the product. There is limited experience with this approach, but it does appear to be applicable to Earth observations, and possibly to other space applications services.
- ***Regulatory measures.*** –Economic regulation (as contrasted with regulation to protect the public health, interest and safety) has been employed where the public interest requires a mechanism to control pricing, entry into a market, service delivery, and industry structure. A typical example is the Federal Communications Commission (FCC) operating under the Communications Act of 1934.[6] In addition to carrying out its regulatory functions, FCC has recently been instrumental in allowing limited multiple entry into certain parts of the telecommunications market. It is necessary to institute some form of regulatory authority when the nature of a service makes a monopoly supplier necessary, as was originally true for the Nation's long-distance telephone system. In the early years of the system, the technology that was available required a single switched system for long-distance service. As technology advanced, at first with broad-band microwave repeater systems, and then with satellites having broad-band capabilities, the necessity for maintaining a long-distance monopoly largely disappeared. Consequently, alternative commercial systems have been allowed to compete with AT&T; many of these rely on satellites. Thus, an advancing technology that brings about changes in the market characteristics of the service system may obviate the monopolistic entity. When such a change does occur, there needs to be suffi-

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thermal Energy Research, Development, and Demonstration Act of 1974, Public Law 93-410, Sept. 3, 1974; *Electric and Hybrid Vehicle Research, Development, and Demonstration Act of 1976* Public Law 94-413, Sept. 17, 1976; and *Magnetic Fusion Energy Engineering Act of 1980,* Public Law 96-386, Oct. 7, 1980.

[5] *Crude Oil Windfall Profits Tax Act of 1979,* Public Law 96-223; approved Apr. 2, 1980 and *Energy Security Act of 1979,* Public Law 96-294, approved June 30, 1980.

[6] *Communications Act of 1934,* as amended, 48 Stat. 1064, 47 USC 609.

cient flexibility in the regulatory framework to permit both open entry and movement toward expanded competition.

- Exemption from other /aws.—ln many cases, the process of setting public policy requires that a balance be struck between competing constituencies, or that different incentives be offered to achieve similar objectives. When the circumstances do call for such a balance, the measures available to the lawmaker include relief from provisions of competing laws. For example, antitrust laws intended to increase competition, and thereby to provide better products and services at lower prices to the consuming public, restrict monopolistic activities of corporations. However, in some instances where the public interest seemed better served by collective action than by competition, Congress has granted statutory exemption from the antitrust laws. Examples of such exemptions include the Capper-Volstead Act of 1922, which allows agricultural cooperatives to market jointly and to set uniform prices for their products; the Norris-LaGuardia Act of 1932, which allows collective bargaining by organized labor; and the Defense Production Act of 1950, which grants a limited exemption to contractors who, at the request of the President, enter cooperative agreements related to national defense. It may be desirable to grant a similar exemption to industries that would agree to combine their resources to develop new space applications technologies.
- ***Reporting and other special requirements.–*** Perhaps the most used policy requirement that has been adopted by Congress in recent times is the mandated report. One reason for these often cumbersome reporting requirements is to oblige the executive branch to attend to planning in a way that does not involve significant amounts of appropriated funds. For example, construction of a specific system such as a new strategic bomber is subject to extensive reporting and review in connection with the large annual appropriation required. A more general issue, such as the strategic posture of the United States or the tradeoffs among various new strategic weapons systems, would not necessarily be given detailed attention if a mandated report were not required. No mandate can ensure that the response will be of high quality, that attention will be paid to the issues specified, or that the deadline for the report will be met. In fact, congressional mandates have been increasingly ignored or given such cursory attention that their original intent has been negated. With the pressures of the congressional calendar making it difficult for members to oversee the tremendous volume of laws already enacted, there are many cases of missed deadlines, inadequate responses, or complete lack of attention which go without significant congressional objection. This causes the process to break down even further. Nevertheless, a mandated report, if properly followed up and if the necessary resources and time exist to complete it, can be a useful policy tool—particularly if it is part of a larger policy initiative, or if the leadership for ensuring its preparation is clearly specified.

In addition to mandated reports, there are several other requirements that may be included to encourage greater attention to overall policy: 1) establishing an advisory mechanism that utilizes relevant expertise outside of the particular agency or department involved; 2) specifying project milestones or "sunset" provisions to be met before additional authority or budget is provided by Congress; 3) requiring coordination with other agencies or with specific international bodies.

Additional Considerations

These general areas of policy development provide wide latitude for responding to the issues facing the civilian space program today, and for generating innovative approaches to emerging questions and future problems. In evaluating specific options that fall within the general types of policy, the following questions need to be considered:

- Is ***it feasible?—I*** n this assessment, the term "feasibility" will be used to imply that prospective policies are consistent with an accepted understanding of the appropriate roles of Government and the private sector, the separation of powers between Congress and the executive branch, etc.; in other words, that the option does not require a revolutionary change in current practice. The assumption is that changes that are less disruptive and evolutionary in character will have a greater likelihood of serious consideration and possible adoption than more revolutionary measures, and that the benefits of the civilian space program, however great, do not justify radical changes in American institutions and practices.

- Is it ***in the public*** interest?—The motivation for making changes to space policy is to serve the public interest and not just to promote a particular constituency or industrial sector. Hence, an additional test for acceptable policy changes would be (among other factors): does this change promise greater public benefit, in lower net costs, better services, more rapid introduction of new services, a favorable distribution of expected benefits, an improved competitive position abroad, or enhanced national security?
- ***Can it be*** implemented?–This again is largely a question of judgment in determining (on the basis of experience or other data) that a desirable policy change may or may not be capable of being implemented in the "real world, " given practical questions of timing, cost, depth and extent of previous commitments, institutional inertia, or an inability to dictate a course of action to other nations. In such judgments, there will always be room for debate. Therefore, wherever it is appropriate in the policy synthesis, questions of U.S. ability to implement a policy will be highlighted.

In summary, the foregoing discussion has focused on the major questions that should be considered in order to evaluate possible policy options. It has also identified the general classes of policy initiatives that appear to be relevant to space applications. The next section will review the major issues and problems with our current situation that prompt the search for new policies and solutions.

SUMMARY OF ISSUES

The search for new policy options is stimulated by the belief that significant new services, and consequent public and private benefits, could result from a vigorous exploitation of current and future innovations in space. The Government may promote such new systems through policies that will, inter alia, lower barriers that may exist; provide new mechanisms for interested parties to cooperate; and, in general, encourage public and private investment in space applications commensurate with the prospective benefits to society.

In this analysis, we proceed from a basic premise—that the existing policy framework, which has served to organize the Nation's initial efforts in space, should be reviewed for possible changes in the light of current and emerging technology, as well as the more than 20 years experience in space operations that the Nation has acquired since Explorer 1. The following factors make the present a particularly appropriate time for review: the advent of the shuttle and the conditions of fiscal stringency that may lead to a reduced effort in large-scale engineering development for NASA; the appearance for the first time of significant economic competition from foreign countries; the rapid development of military space systems; and the prospect of new commercial opportunities in remote sensing and materials processing.

The flaws in our existing policy cannot be attributed to a single overriding cause. In a number of ways, it fails to provide the kind of stimulus and guidance to our national space efforts to ensure that the country's public and private resources are used in the most beneficial fashion. This shortcoming is highlighted by the fact that several foreign countries intend to develop their own space applications systems, some of which will be more advanced, and more suited for applications, than are comparable U.S. systems. The growing domestic interest in space is evident in industry initiatives and congressional hearings on space policy,[7] recently introduced legislation,[8] the growing number of voluntary space associations (see ch. 5); and efforts by individual entrepreneurs to develop private launch systems and satellites. All of these varying developments reflect the remarkable maturation of space technology over the past decade, as well as the great but unfulfilled promise that further development offers for delivering useful services, gaining international prestige, and satisfying the human spirit of adventure.

Implicit in the concerns of the constituencies mentioned above is the claim that, compared with the potential benefits to be achieved, U.S. investment in civilian space applications may be misdirected or too low. This claim raises two important questions: 1) What is the relative importance of increased public or private investment in space applications as compared with alternative investments (in defense, social programs, new plant and machinery, etc.)? 2) What are the possible benefits or returns, and to what degree can one ascertain their extent and magnitude?

These issues be will be implicit through the sections that follow; briefly, we can respond thus. First, the claim that we are investing too little in space applications does not imply that we are also investing too much in other worthwhile areas. Furthermore, opportunity costs in the public policy arena cannot be rigorously compared. The resolution of the annual conflict among alternative allocations of public resources is necessarily political, subject to all the vagaries of human judgment, prejudice, and intuition. Much depends on the overall resources available, and hence, on the state of the national economy and the Federal budget. To require that investments in space applications be explicitly compared with other alternatives is to apply a constraint that is inappropriate to public policy issues. Nevertheless, in a period of fiscal restraint and intense scrutiny of all Government expenditures, the space program can expect to have to defend its claim to a share of Federal revenues, and to justify its programs by arguing that they contribute to national goals such as defense or increased industrial productivity.

This situation is made difficult insofar as many of the societal benefits are not immediately realizable or are difficult, if not impossible, to quantify. They include such abstract notions as international prestige, national self-image, and incentives to individual achievements; a single mission or project is often not easily identified with a specific set of benefits. For example, the successful flight of a meteorological satellite does not generate public attention in the United States. However, not only do large segments of the U.S. economy depend on the accurate data such satellites provide, but other nations around the world are eager subscribers to this information and see the United States in a more positive light because of this service. It is the accumulation of many such small but significant positive effects that constitutes the sum of intangible benefits from the national space effort.

Because of the effects of space investments are derived primarily from many small, though by no means insignificant programs, it is difficult to sustain public investment at a level and scope appropriate to the potential of the consequent benefits. Partly for this reason it is important to consider public policy incentives for private sector space investments that could complement or substitute for direct public expenditures. Private investment will occur only if the benefits (usually in the form of direct profits) to the private investor are relatively assured (i.e., low risk), and are of sufficient magnitude to be attractive in comparison with other alternatives. Policy incentives must promote these conditions while ensuring that the public and national interest are also served.

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[7] *United States Civilian Space Policy,* hearings before the Subcommittee on Space Science and Applications of the Committee on Science and Technology, U.S. H. R., 96th Congress, 2d sess., July 23, 24, 1980, No, 152, USGPO, Washington, 1980.

[8] For example: *The Space Industrialization Act of 1979;* hearings before the Subcommittee on Space, Science and Applications, of the Committee on Science and Technology, U.S. H. R., 96th Congress, 1st Session, on H.R. 2337, May 22,23, and June 26,27, 1979, No. 47.

[9] For example: Carl Sagan's "Planetary Society, " which has an active, informed and rapidly growing membership.

The issues discussed in this chapter derive from, among other sources, a series of workshops held at OTA for the purpose of identifying the major issues or concerns facing the U.S. space program (table 1, in ch. 3) and suggesting policies that might be adopted to resolve those issues.

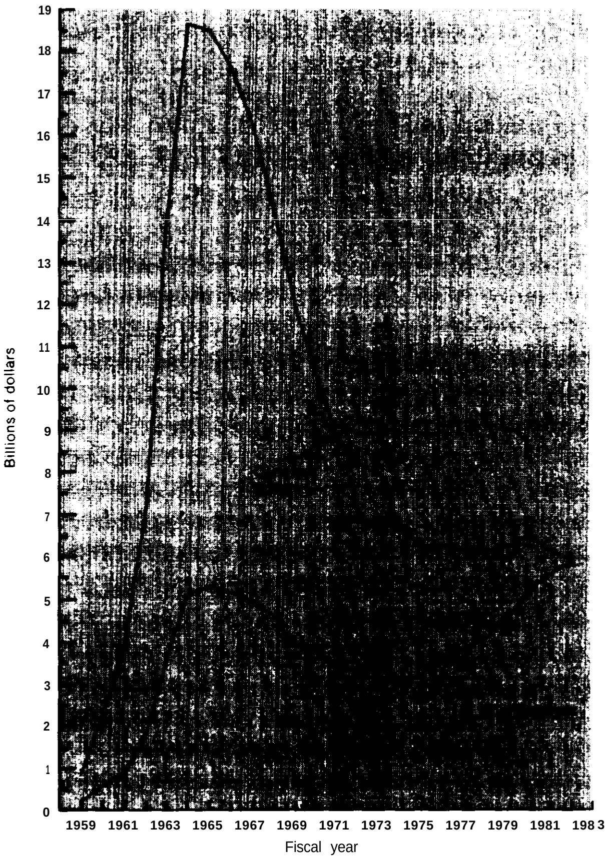
Need for Consistent High-Level Attention to Space Policy

Current space policy does not translate easily into a set of specific goals, program areas, or mission opportunities. Hence, during periods when there is a national preoccupation with social, defense, or economic issues that bear no direct relation to the civilian space program, the process of planning and budgeting for specific missions may fall victim to lack of high-level attention and focus. Because there is no current long-term commitment to specific goals (after space shuttle development is complete), and because the most recent presidential statement on space program goals (by President Carter in 1978)[10] was vague with respect to the content and timing of future objectives (beyond "utilization of the shuttle"), annual budget and program decisions have tended to be made ad hoc. When decisions are made in the context of annual budget preparations, they unfortunately are biased by the restricted nature of the forum (primarily discussions between the agencies with space allocations in their budgets and the Office of Management and Budget), and by the tendency to look for short-term economies, to shrink or limit programs and future-year costs, to refine and improve management, and to fit the program into a budget target. While these are necessary and important management considerations, they are not suited to developing and identifying a creative program or a national commitment to long-term space program goals. For consistent, long-term policy objectives to be developed and carried out, the budget process must necessarily follow policy guidance, and not the reverse. Without such policy commitments, the annual budget process will result in mission deferrals, stretched schedules, and even cancellation of well-developed projects, adding up to a waste of scarce resources. All of these have already occurred in recent NASA budgets.

The Executive

In the Carter administration, several major interagency reviews of space policy were carried out under the aegis of the National Security Council, and in the process a Policy Review Committee (PRC) for space was established with the Director of the Office of Science and Technology Policy (OSTP) as the chairman. The issues reviewed during this period involved principally space applications and the civilian/military interface, and led to three (classified) Presidential directives and several public statements concern-

Figure 16.-Civilian Space Budget



NOTE: 1959 DOD transfer = $146.6 million for appropriation, $640.6 million for constant dollars, 1961 DOD transfer = $2.7 million for appropriation, $11.0 million for constant dollars; transition quarter (*period between 1976 and 1977*) = $932.2 million for appropriation, $1,638.8 million for constant dollars.

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[10] "White House Fact Sheet, U.S. Civil Space Policy, office of the White House Press Secretary," Oct. 11, 1978.

ing: 1) assignment of responsibility for operational satellite Earth-sensing systems to NOAA; 2) transition to commercial operation for Landsat; and 3) general civilian space policy.[11] In the Reagan administration, the PRC (Space) has been abandoned and an independent review of the Carter administration decisions and other space program questions is underway (see ch. 6 for a description of the review). One of the principal participants in this review is the Director of OSTP. In the 1976 legislation establishing OSTP, the Director is given a broad assignment that includes providing the President with analyses of major policies, plans, and programs involving science and technology. Among the priority goals delineated for science and technology is “advancing the exploration and peaceful uses of outer space.”[12] OSTP can act as a focus for space policy development, provided: 1) the President determines that he wants OSTP to play such a role, and 2) there are enough personnel and funds available for the Office in addition to its other responsibilities for science and technology policy. Currently, OSTP'S limited budget and staff resources (approximately $1.5 million in fiscal year 1982 and 11 permanent positions) make it difficult for the Office to assume a major continuing role in evaluating space policy.

Despite the efforts of the Carter administration, two major problems with Executive direction of the space program have arisen in recent years: 1) ***failure to identify and commit to major new goals,*** and 2) ***failure to implement programs*** to accomplish goals already announced or identified. These problems suggest that the Executive has been ineffective in focusing its attention on the space program, because of pressure from the external environment (such as budget constraints and an emphasis on national issues that are not clearly addressed by the civilian space program) and because of internal difficulties (such as the administrative structure of NASA, and the determination to complete current large programs such as the shuttle). Better procedures are needed periodically to focus high-level attention on space program needs, procedures that will fix a continuing defined responsibility for developing space program goals and objectives, reviewing the plans to achieve the objectives, and identifying the resources that may be required. This responsibility would include periodic public presentation of the goals and objectives developed by the executive branch to Congress for debate and ratification. A forum for implementing these procedures could have a broad scope, defined in detail by Congress, or its responsibilities might be described by Congress in general terms, with its detailed structure to be determined by the executive branch.

It should be noted that, in its original form, the legislation establishing NASA also created a coordinating mechanism, the National Aeronautics and Space Council (NASC), whose responsibilities included civilian/military coordination and, more significantly, development of “a comprehensive program of aeronautical and space activities to be conducted by departments and agencies of the United States. ” The Council was abolished by President Nixon in 1973 at the same time that the Science Adviser's Office was removed from the Executive Office of the President. The President's Science Advisory Committee was also abolished. This now defunct NASC is one example of an executive branch mechanism that could satisfy the needs identified above. NASC'S original functions and composition should be reviewed in the light of developments in current technology and changes in agency relationships. The scope of its responsibilities would have to be clarified: would it be limited to civilian programs only? to the **civilian/military relationship?** or extended to include both civilian and military programs, and private sector activities?

The Legislative

Congress, insofar as it oversees and reviews executive branch agencies and programs and initiates and passes on legislation, is an essential part of the policy process. Committee hearings bring forth critical issues for public airing and debate, and staff papers, investigations and congressional

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[11] Ibid.

[12] *National Science and Technology Policy, Organization and Priorities Act of 1976,* Public Law 94-282, May 11, 1976.

[13] Reorganization Plan No. 1 of 1973, 38 Federal Register 9579, Apr. 18, 1973, 87 Stat. 1089, abolished the National Aeronautics and Space Council together with its functions, and the Office of Science and Technology, efective July 1, 1973.

agency reports all contribute to the review framework. In addition, major policy initiatives frequently originate in Congress. The COMSAT Act,[14] for instance, had its origins largely in Congress, though it was well supported at the time by the president and his advisers.

Congress' watchdog role, primarily determined by the yearly budget cycle, often leaves congressional committees at a disadvantage with regard to setting policy. They can be so caught up responding to initiatives from the president, that they are unable to take the time to formulate policy or to form a long-term vision of national programs.

In addition, the present committee structure, in which several different committees have jurisdiction over different parts of the space program, makes it difficult to consider the program as a whole. In recent years, there has been no central focus in Congress for space matters. The Congressional Space Caucus recently formed in the House of Representatives may provide an informal forum for discussion of space program priorities and direction within Congress. Its formation reflects the concern of some members about the uncertain direction of the U.S. space program. Neither it nor policy studies can substitute for a broader, sustained debate on the place of the space program in the totality of national objectives, in which all the major actors are represented.

Institutional

In developing space telecommunications, the U.S. founded new national entities and international structures that would design and procure satellites, operate the systems, and provide services to international users. These measures enabled private capital to flow into the system, resolved Government/private sector relationships, and started the commercialization process that led to a larger array of services. Many of the national and international problems confronting the united States at the time COMSAT and INTELSAT were established have analogs in the current situation in remote sensing and in other applications areas. For example, there is no clear guidance regarding the nature of commercial involvement in operational systems, whether existing or new entities should play a role, whether Government will purchase services or fly its own systems, or whether the United States will favor international competition or a cooperative framework. It should also be noted that today's circumstances have characteristics that are quite different from those encountered in the early 1960's. Then, there were no reliable vehicles to launch competitive communications satellites beyond those controlled by the United States and the Soviet Union; there were no real alternatives to cooperation. The character of the market was also very different, International communications was a well-developed business involving long-distance underwater and subsurface cables, high-frequency radio, and microwave links for short distances. Government agencies or private concerns were engaged in supplying services, so that adding a satellite repeater was a relatively straightforward step in extending and improving this existing business base. Customers were identified and demand was already established, factors which provided a solid base for the rapid development of the space segments—particularly with the better quality service that was provided.

A major issue therefore is: Are there alternative institutional frameworks that would facilitate development of desirable new space applications services and overcome barriers that exist, whether from lack of a clear national policy, underdeveloped markets, or other uncertainties? An associated issue is: Can the private and public sector roles be more clearly defined to assist in more effective and timely exploitation of space applications opportunities? A further question of importance is: Should NASA be given responsibility to operate space applications systems?

International

Space activities (outside of short-duration vertical sounding rocket flights), unlike many other areas of national endeavor, cannot be confined to the region over a given nation's territory. Orbital flight inevitably brings the space vehicle over other nations. In the 1967 Treaty on Principles *Governing the Activities of States in the Explora-*

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[14] Op. cit., *Communications Satellite Act of 1962.*

tion and Use of Outer Space, Including the Moon and Other Celestial Bodies, "outer space" was recognized as a nonappropriable area analogous to the high seas, and hence open to use by all nations. Policy regarding the well recognized international character of space activities was established in the NAS Act, where the guideline of "peaceful purposes for the benefit of all mankind" was fundamental to the U.S. program. In addition, U.S. activities were to be conducted so as to contribute materially to the following objective (among others): "Cooperation by the United States with other nations and groups of nations in work done pursuant to this Act and in the peaceful application of the results thereof."[15]

in applications, there are several national concerns that may limit our ability to obtain international agreements on the development and use of space systems. The United States has traditionally advocated open access to outer space and free commercial competition, but this position has been increasingly challenged by Communist and Third World countries which favor restrictions on space activities. In pursuing new opportunities for applying technology to space, the United States must weigh the national benefits accruing from aggressive competition against the need for, and benefits from, broader cooperation in the international arena.

The issues to be addressed include: 1) What benefits has the United States received from its cooperative programs? 2) How is the desire for cooperation to be reconciled with maintaining U.S. preeminence? 3) How should the United States respond to the growth of competitive space applications programs in Europe and japan? 4) Are there benefits to be gained by internationalizing civilian Earth observations satellite systems? How can they be realized? 5) What framework would enable systems to be established which would gather global information on topics of broad common interest, such as ozone concentrations, carbon dioxide levels, and biomass inventory?

POLICY SYNTHESIS

The kinds of legislative and policy options, the categories and criteria for their evaluation, and the major issues involved, have now been identified. This background enables us to outline a number of specific policy options available to Congress for more detailed consideration. **In the next section, we integrate selected options into compatible and coherent packages.** The various options are organized by the issues which suggest them.

Need for High-Level Attention to Space Policy in the Executive Branch

The range of responses to deal with this issue is very broad. Possible actions by Congress include the following:

- Reestablish the National Aeronautics and Space Council (NASC).
- Form a Presidential or National Commission
- Establish a new department.

Reestablish the National Aeronautics and Space Council (NASC)

The NASC was disbanded in 1973 together with the Office of Science and Technology (OST) and the President's Science Advisory Committee (PSAC), as part of a move to reduce the size of the Executive Office and remove so-called "advocacy" groups from immediate proximity to the President.[16] OST was reestablished by legislation (as OSTP) in 1976[17] but no strong constituency emerged to press for the reestablishment of NASC at that time. The original charter for NASC in the 1958 NAS Act implied a strong need for conflict resolution and better coordination among agencies engaged in space activities. At present, the

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[15] Op. cit., *National Aeronautics* and Space Act of *1958*.

[16] Op. Cit., Reorganization Plan No. 1 of 1973.

[17] Op. Cit., *National* Science and Technology *Policy, Organization* and Priorities Act of 1976.

needs for high-level coordination as well as for "a comprehensive program of aeronautical and space activities . . . ," as stated in the original NASC legislation are of critical importance.[18] A reestablished NASC might provide a suitable forum to focus attention on space program goals and objectives, problems of program coordination, competing claims of different interest groups, and a variety of other matters. Whereas the old NASC was composed of members from NASA, the Departments of Defense, Transportation, State, and the Atomic Energy Commission, membership in a new NASC should be broadened to include Agriculture, Interior, and Commerce (NOAA). The original NASC was chaired by the Vice President, who was considered a neutral arbitrator with access to the President; with the addition of observers from the Office of Management and Budget and the President's Science and Technology Adviser, a new NASC would bring together all the major Government space interests. It could serve to generate the needed commitment to specific program content, aid in preparation of annual budget proposals, and give the space program higher visibility with the President. The Council probably should have a central staff working for an Executive Secretary, although the staff could be primarily composed of detailees from the agencies involved. Only a few professionals would be needed on the staff in order to perform the basic Council tasks. However, adding the requirement of an annual report would increase staff size appreciably. Occasional reports to the public on space program goals, plans, or achievements could be part of the output of a core staff.

The Reagan Administration does not appear to favor new entities in the Executive Office, although topical committees of the Cabinet have been formed for specific policy areas. The NASA Administrator does not have Cabinet status and therefore is not represented at this level. An exception has been the appointment of vice President Bush as chairman of a committee for regulatory review, demonstrating that it is possible to have the administration accept a new entity in the Executive Office under the chairmanship of the Vice President; however, the space program does not appear to have high enough priority in the administration for this sort of treatment. Therefore, it may be difficult for Congress to establish any new mechanisms for defining and coordinating space policy, whether it is a new NASC or another option.

The existence of an NASC would enable agencies to focus their policy concerns at a high level, with the prospect of influencing critical decisions. It would remove overall program content and strategy decisions from a strictly budget-oriented setting, as is the case today. This would greatly enhance the likelihood that long-term programs and goals can be agreed upon and effectively pursued. By having the Office of Management and Budget (OMB) represented as an observer on the Council, deliberations would have the benefit of a realistic view of the budget situation. It should be understood that the deliberations of a reconstituted NASC would not receive adequate attention from either the agencies or OMB, unless there were direct Vice Presidential interest and involvement. This would carry with it the prospect of direct contact with the President, and would make the difference between a Council with little or no power and a Council with an important role in the policy process.

Annual expenditures by the Federal Government for civilian and military space activities exceed $10 billion, all of which is "discretionary," i.e., not subject to a mandated formula or specified service. A body such as the NASC would enable these expenditures to receive the high-level review and attention appropriate to their national significance.

Committee of the National Security Council (NSC) or a Subset of a "Cabinet Council's" Responsibilities

Because it concerns the internal management of the Executive Office, this option is not amenable to congressional action. It has been included here for the sake of completeness.

In the Carter administration, the lack of a high-level policy focus in the executive branch was recognized as a problem, and the solution was the formation of a Policy Review Committee for

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[18] Op. cit., *National Aeronautics Space Act of 1958,* title II, p. 4, sec 201, d-2.

Space (PRC-Space) within the structure of the NSC. (In the Carter administration, there were various PRC'S dealing with specific national security areas). The chairman of the PRC-Space was the Director of the Office of Science and Technology Policy (OSTP). By contrast, the Reagan administration has favored routing space issues through a new "Cabinet Council" managed by White House staff, with advice from the Director of OSTP and the Special Assistant for National Security Affairs (see ch. 6).

By using the NSC structure for space policy review there is a rather strong orientation toward national security and military affairs. The civilian space program, while sometimes having a strong international impact, has traditionally been separated from specific military and national security programs. NSC is managed by a foreign-policy oriented staff with little of the necessary background in dealing with commercial or technological concerns.

While the OSTP Director is a relatively neutral figure, the stature of his office vis-a-vis the White House has varied considerably and does not compare with that of the Vice President. On the positive side, NSC has typically been a very important focal point for setting policy in recent administrations, so that issues raised in this forum usually reach the President for decision. This provides a degree of access not easily matched except by OMB and the key White House staff. Whether this situation will continue in the Reagan administration is not clear. In addition, NSC is equipped to consider issues dealing with the highly classified military and intelligence space programs, by individuals fully cleared for access to the classified aspects. This is particularly important for such common systems as the space shuttle and tracking and data relay systems, and in connection with the transfer of technology from the classified to the civilian programs.

Use of the new "Cabinet Council" method of reviewing space policy forces these issues to compete with a much larger array of other policy concerns for the very limited staff time available to support the councils. Without a dedicated staff, adequate attention is not likely to be given to understanding the issues and to the development of viable options. On the positive side, the Cabinet Council may allow for significant high-level attention to whatever proposals reach its agenda.

Presidential or National Commission

A device that is occasionally employed to investigate a broad area of national interest is a presidential or National (implying congressional and private involvement) commission, board, committee, or council. Examples are:

- ***The Commission on Intergovernmental Relations.*** A 26-member bipartisan permanent body with State and National Government representatives, from both the legislative and executive branches, and members from the general public whose purpose is to review and recommend improvements in the Federal system.
- ***Water Resources Council. Established*** to maintain a continuing study of national water requirements. The Council reviews plans of river basin commissions, assembles these plans and submits them to Congress via the President. It also administers a program of Federal grants for water and land resource planning.
- ***Procurement Commission.*** An ad hoc group for reviewing Federal procurement policy, with public and private membership and a limited lifetime (it has completed its work). It prepared a comprehensive set of policy recommendations and procedural changes.

One possibility for space is to charter for a specified term, a "National Space Commission" with membership from the general public, State and local governments, industry (particularly aerospace and electronics firms), academia, Congress, and the executive branch—NASA, State, DOD, Interior, Commerce, and Agriculture. The Commission would be charged with reviewing and assessing the civilian space program and its benefits, and recommending long- and short-term objectives, and a time frame for their achievement. The product of the Commission would be a major report, recommending short- and long-term goals for the U.S. space program. The Commission would be publicly supported; following its report, congressional hearings could be held on its recommendations, and legislation prepared for consideration by congress.

Such a forum enables participation from a broad set of interests in developing program goals; it operates in a manner that is outside normal channels and hence would be less threatening to the annual budget preparation process; it would be public and could solicit public input as appropriate; and it would serve as an expression of broad national and bipartisan support for the civilian space program. In order to provide a specific objective for such a group, a major report should probably be specified, with annual updates for the life of the Commission.

A National Space Commission, because of its public, short-term nature, could not substitute for a means within the administration to resolve issues, develop policy proposals, review goals, and set strategy for the space program. The Commission therefore is complementary to the previous two options, although it would deal with many of the same issues. The Commission would have the advantage of being able to evaluate public response and support, and to focus that support on specific goals. It also provides a device for full discussion of congressional, executive branch, and private sector views in a constructive setting.

Establish a New Department

This concept would place NASA in a larger Cabinet-level structure, perhaps one that incorporated a group of science and technology agencies. The principal focus for space policy would be a Cabinet officer responsible for setting space goals, as well as integrating these goals into a larger science and technology policy framework. The following choice of functions to be grouped together is largely illustrative–a considerably more detailed discussion would be required to treat this subject adequately than is appropriate to this report.[19] If, for the purposes of this assessment, we designated it the Department of Basic and Applied Sciences, it might have a Research Administration with components from the NSF, NASA, and DOE; a Space Operations Administration with responsibility for launch vehicle development and operation, manned flight, satellite integration, tracking and data acquisition; an Environment and Natural Resources Administration with land, atmosphere, and ocean activities from NASA, NOAA, DOE and possibly the U.S. Geological Survey from Interior; an Industrial Technology Administration with the National Bureau of Standards, Patent Office, and applied technology programs from NSF; and an Energy R&D Administration with the core DOE programs such as solar, conservation, fossil, nuclear, and fusion. The department could have a special projects office for interdisciplinary issues that require broad contributions such as communications and information, science and technology, or for limited-life projects such as robotics development (to assist in accelerating commercialization of this new technology). In such a department, responsibility for leadership in generating space program goals and objectives would lie with an Administrator for Space Operations, assisted by others—Research, Environment and National Resources, Energy, Industrial Technology, and Special Projects. These components would be responsible for generating programs in space science, weather and meteorology, Earth observations, space manufacturing, and telecommunications. Together, they would constitute the civilian space program. Coordination with DOD and national intelligence space programs would still be required, and for this purpose a Cabinet-level Space Council might also be desirable to resolve issues that arise, to provide a forum for program coordination and to enable consideration of other aspects, such as foreign policy considerations (which would be supplied by the Secretary of State).

This option would be extremely difficult to implement, since it would involve many congressional jurisdictions and appear to threaten existing agency constituencies. On the other hand, the Reagan administration has indicated that it plans to dismantle the Department of Energy, and this could provide the stimulus for giving serious consideration to formation of a new department by grouping together high-technology agencies, including the R&D elements from the present DOE. Many foreign countries, including Japan and most of Western Europe, have ministerial-level departments dealing with science and technology.

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[19] For example, see reports of the U.S. House of Representatives Committee on Science and Technology in 1967, 1972, and 1977.

A new, high-technology R&D department to deal with space policy issues would facilitate access to the President. It could also strengthen bargaining with OMB in the budget process, and might even (depending on the other agencies and functions that were included in the new department) result in economies in areas where common support functions can be combined (procurement, administration, facilities, personnel, etc.). It is also possible that better use of supporting laboratories would result from incorporating them into a larger departmental structure.

LEGISLATIVE BRANCH

In the future, Congress could take a much stronger hand in formulating space policy and coordinating the different national space programs. Congress played a major role in the initial stages of the U.S. space program by drawing up the NAS Act, and Members of Congress were leaders in helping to focus national attention on space exploration. Other critical policy decisions, such as the COMSAT Act in 1962, were also initiated by Congress. Both the House and Senate formed full committees to oversee civilian space activities, while assigning responsibility for military space programs to their respective Armed Services Committees.

During the Apollo years, Congress supported major programs proposed by the executive branch and voted increasing annual budgets for NASA. However, in the late 1960's and early 1970's, NASA budgets and program proposals came under increasing attack as being too ambitious for a period when domestic social programs and the Vietnam war required ever-larger national commitments. Despite a strong core of congressional supporters, congressional critics on the Senate Appropriations Subcommittee on HUD and Independent Agencies succeeded in reducing NASA plans for major post-Apollo programs. NASA's space budget reached a low of $2,758.5 billion in 1974, down from a 1965 high of $5,137.6 billion (in current dollars; if inflation is taken into account, the differences are much greater).

In the mid -l 970's, both the House and Senate restructured their authorizing committees for space activities. In the House, responsibility for most of the civilian space program authorization and oversight shifted from several subcommittees of the Committee on Science and Technology to only one, the eight-member Subcommittee on Space Science and Applications of the Committee on Science and Technology; in the Senate the Committee on Space was disbanded and responsibility for space matters was assumed by the nine-member Subcommittee on Science, Technology, and Space of the Committee on Commerce, Science, and Technology. In addition to, the military responsibilities of the Armed Services Committees, space activities in Commerce, Interior, Agriculture, and Energy Departments are overseen by different committees.

In recent years, Congress has addressed many of the policy issues discussed in this report; in particular, it has dealt with the uses of the space shuttle, the transition to an operational remote-sensing system, international competition, and commercialization of space technology. The absence of a coherent and comprehensive national civilian policy has surfaced as a recurrent concern, and hearings on this subject were held by both Houses in 1979z0 and 1980.[21] In the Senate, S. 212, the "National Space and Aeronautics Policy Act of 1979," and S. 244 "to establish national space policy and program direction" were introduced. Both bills proposed establishing long-term programs in accord with explicit policy principles, with S. 212 specifying particular projects as well.

In the House, hearings were held in May and June 1979 on H.R. 2337, the Space industrialization Act of 1979,22 which called for establishment of a national Space Industrialization Corporation to encourage public-private exploitation of commercial opportunities in space. In both 1979 and 1980, the House passed H.R. 2335, the Solar

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"""U.S. Civilian Space Policy," hearings before the Subcommittee on Science, Technology, and Space of the Committee on Commerce, Science, and Transportation, U.S. Senate, Jan. 25 and 31 and Feb. 1, 1979.

'l" United States Civilian Space Policy," hearings before the Subcommittee on Space Science and Applications of the Committee on Science and Technology, U.S. House of Representatives, July 23 and 24, 1980.

[22] ''The Space industrialization Act of 1979, " hearings before the Subcommittee on Space Science and Applications of the Committee on Science and Technology, U.S. House of Representatives, May 22 and 23; June 26 and 27, 1979.

Power Satellite Research, Development, and Evaluation Program Act of 1979,[23] which would have authorized $25 million for R&D on solar power satellites. In 1981, the Space Policy Act of 1981 was introduced (H. R. 371 2), and general hearings on civilian space policy were held in September.

The problems of coordinating policy and establishing long-term goals are mirrored in Congress' own activities. To a much greater extent than in the executive branch, Congress' ability to deal with these problems depends on informal and personal responses, rather than institutional or legislative changes. The problems facing sustained and broad-based congressional attention to space policy are:

- ***Not a high national or regional priority.*** — Space programs and policy have not recently been high on the national agenda as compared with questions of social, economic, and foreign policy. In addition, constituent interests force relatively few Representatives or Senators to consider space (a number of Congressmen, including former astronauts, have strong personal interests in this area and have contributed to the increased attention to space policy in recent years).
- ***Staff size and experience.*** —The change from full committee to subcommittee oversight, coupled with recent Senate staff cutbacks, may make it more difficult for Congress to deal with the many issues involved.
- ***Jurisdictional overlap and committee relations.*** –The different committees and subcommittees with responsibilities for various civilian programs create a need for coordination, if oversight of national programs and integration of national policy is to be accomplished. Relations between civilian and military programs are particularly sensitive. In previous years, Congressmen sitting on both the Space and Armed Services Committees provided informal coordination. Today, only one Senator and one Representative belong to both the space subcommittees and Armed Services Committees or Intelligence Committees.

Given strong enough leadership and sufficiently widespread perception of the importance of the issue, institutional or jurisdictional barriers to a comprehensive consideration of space policy are not insurmountable. joint hearings, multiple referrals of legislation, and ad hoc committees or additions to committees are several ways to cut across established territories.

In recent years both the House and the Senate have criticized many specific administration actions as well as the lack of an overall policy. So far, none of the proposed reforms of space policy or initiatives for major program changes have been adopted. However, the continued absence of executive leadership guarantees that Congress is more and more likely to take the initiative in setting long-range goals for exploiting the shuttle, commercializing space technologies, and meeting international competition.

INSTITUTIONAL CHANGES—CLARIFYING THE PUBLIC-PRIVATE SECTOR ROLES

In space applications, the services and products involve both Government and private firms and institutions. The multitude of interests and players has raised questions concerning the appropriate role of each in developing and operating applications systems. In one area, weather and atmospheric observations, the Federal Government has traditionally collected the data and made it freely available as a public service. A similar pattern has been established in oceanographic observations. In communications, Government performed much of the early research and demonstration, but industry and regulated entities have developed the platforms and supplied the services—subject to regulation by FCC and consistent with agreements under the International Tele-

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[23] "Solar Power Satellite," hearings for the Subcommittee on Space Science and Applications of the Committee on Science and Technology, U.S. House of Representatives, Mar. 28, 29, and 30, 1979.

communication Union (ITU). In satellite Earth observations the Government has performed much of the research, developed and demonstrated the platforms and distributed the data. Private industry has supplied users with value-added services. (By contrast, aircraft surveys are normally done by private industry without Government involvement in any phase of their work.) in space manufacturing and space transportation, Government has taken the lead, but private sector involvement is growing. An important issue therefore ,is to clarify ways in which the private and public sectors might work with one another.

Space Telecommunications

Initially, international satellite communications were established as a Government-regulated monopoly through INTELSAT and the U.S. representative, COMSAT (see ch. 8). As the technology has advanced and new customers for it have been identified, domestic satellite services have been established and competition for domestic services has been allowed. Maritime communications are being developed along the lines of INTELSAT, through the international maritime satellite organization (INMARSAT), in which COMSAT is also the designated U.S. participant. INMARSAT came into existence in 1979 in recognition of the desirability of instituting a single (monopoly) system for maritime services while encouraging competition for certain other communications satellite applications.

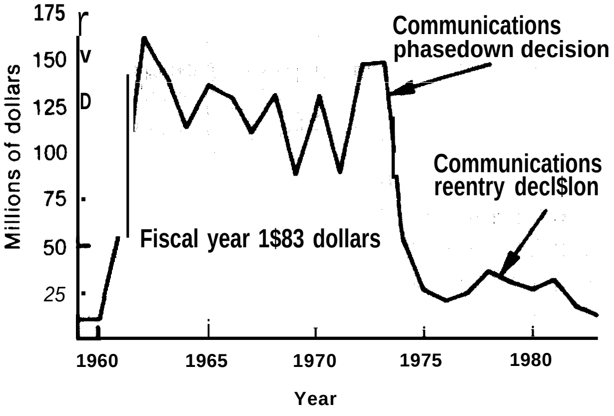
In the future, it appears that lower costs, more demand for capacity, and greater diversity of services will characterize the domestic communications industry. Direct broadcast satellites for television signals to the home are likely in the mid-1980's. Business services are expanding, especially for data communications and specialized functions. The industrial firms that can act as suppliers are available, and the existing service markets provide an important revenue base for future new ventures. The principal areas of concern are the availability of the electromagnetic frequency spectrum in the light of competing demands for services, international control of assigned orbital positions for satellites (through ITU), and domestic regulation of technical and commercial characteristics.

Clarifying the R&D Role of Government in Space Communications.

An important policy option is to clarify and make more explicit the role of NASA in supporting R&D needs for space communications. In order to accomplish this, it may be desirable to legislate NASA's responsibilities in R&D for advanced communications satellites. The NASA program in communications was cut back for most of the decade of the 1970's (despite the general guidance of the NAS Act and COMSAT legislation) (see fig. 16), However, NASA had earlier contributed significantly to progress in space telecommunications, providing much of the technology and systems in use today. NASA could contribute to the solution of current and future problems, such as utilization of the 30/20 GHz frequency (see ch. 3). A continuing telecommunications technology program would include fundamental work at higher frequencies and demonstrations of technology and systems.

It will be very important for industry and NASA to cooperate in defining the appropriate high-risk areas for Government support and the boundary between Government and industry for development of specific systems. Industry can and should work with NASA to sponsor cooperative communications technology demonstrations. To ensure adequate consultation between NASA (as a lead agency for this work) and industry, an ***industry-Government consultative committee*** could be

Figure 17.—NASA Funding for Communications Satellite Technology (In constant year 1983 dollars, i.e., adjusted for inflation)



SOURCE National Aeronautics and Space Administration specified that would consider space communications research and technology needs. On such a committee, in addition to NASA, Government would be represented by DOD, NTIA (Commerce), State, and FCC, while the industry representatives would include aerospace contractors, the common carriers, COMSAT and other space services suppliers. The deliberations of this committee could be submitted to the Congress as part of the annual budget. A committee with a similar function already exists in high-energy physics, called the High Energy Physics Advisory Panel (HEPAP). It includes all the interested parties in the field and is sponsored by the principal agency responsible, DOE. HEPAP serves to resolve the various independent views of what is needed and periodically presents an integrated plan for new facilities and research needs.

Open-ended assignment of a space communications R&D role to NASA might be difficult to sustain for several reasons: 1) uncertain and possibly larger budget needs would be resisted by OMB and the administration; 2) users might have little role in NASA demonstrations, with the result that unnecessary and uneconomic technologies might be pursued (i.e., there is the danger that it would become a technological "hobby shop"); and 3) NASA might create unrealistic expectations by demonstrating sophisticated new technology not ready for commercial introduction. On the other hand, remaining silent regarding the NASA role invites the type of decision that was made in the early 1970's, when the NASA communications satellite platform and technology demonstration program were terminated. The consequences of this decision are covered in chapter 4.

By specifying that NASA should perform communications satellite R&D, including demonstration of technologies and platforms, and also specifying that there will be formal user and industry involvement in identifying the extent and nature of the program, the open-ended nature of the assignment can be modified. Such a consultative process can serve as a forum for bringing out independent views and ensuring the relevance of the NASA program. One danger of such a mechanism is that industry may press for too large a role for NASA, since their incentive is to minimize risk and to push NASA to carry out tasks that industry might otherwise be expected to do. Given NASA's desire to maintain its budget and institutional structure, it can be expected to acquiesce. The example of the HEPAP is instructive in this regard. For it the incentives are very similar: have the Government do more, expand, press forward faster, etc. The counterbalance is the competition and rivalry among the various research groups, and the pressures of other agency demands, OMB, and eventually Congress. Within a communications committee, such pressures can be counterbalanced by competition between companies, Federal agencies, OMB and Congress. DOD's role would bean additional factor. By including DOD in the consultative group, the technology base that is being supported for military purposes would be represented directly. Not all of the developments could be discussed, but general knowledge of classified programs could be a valuable asset in discussions of technology needs.

If in addition to acting as consultants, the industry also took a more active role in financially supporting demonstrations of new satellite systems (see Communications Issue, ch. 3), its own stake in the type and direction of work that is done would be greater. Because industry had a strong financial interest, the development work done would be more likely to reflect the genuine needs of industry. in sum, the above suggestions could lead to a role for NASA that represents a balance between technology push and demand pull.

R&D to Support Regulatory Decisions

Regulation is always the product of balancing among the affected interests. In the balancing process, it is important that the regulatory authorities have the best possible technical information available. The ultimate decisions will reflect their grasp of the technology as well as political and economic constraints, the biases of the people involved, and the effectiveness of the various lobbying groups. The regulatory body for communications, FCC, has an R&D section and a technical staff to interpret the impact of new technology on regulations, and vice versa. But the exploding telecommunications and information technologies have created serious overloading of this staff and their limited budget. It would be unrealistic to consider space communications experiments and demonstrations to be within their capability. However, both nationally and internationally, regulations are being made that control the numbers of satellites that will be permitted (by controlling synchronous orbital slots), their power levels and signal characteristics, the frequencies used, and a variety of other technical details. Information for these decisions comes from a variety of sources–some private (like Bell Labs and COMSAT Labs) and some Government (e.g., DOD, NBS, NOAA, and NASA), but there is no lead agency for space communications R&D to support regulation. This suggests the following policy option:

Modify NASA's legislative charter to direct the Agency to pursue communications R&D to support the needs of prospective regulatory actions, both nationally and via ITU, internationally. internationally, the United States has much at stake in the allocation of orbital slots for satellites, the assignment of frequencies, and the technical characteristics of allowable signals and signal strengths. The United States should also be prepared to take stronger action to ensure more realistic decisions in ITU. These decisions are often driven by unwarranted fears of smaller nations, based on poor technical information, and by political objectives. Both of these aspects should be addressed, the first by better dissemination of technical information, perhaps by a traveling team of experts with equipment capable of demonstrating essential data, and the second through stronger leverage from the State Department. A high-level space policy mechanism such as the NASC could provide the proper exposure at the White House for these international political measures, and a separate subgroup for international space communications may be desirable.

Clarifying the NASA role would enable better planning of space communications research and demonstration programs by the agency and help to provide a more competent and predictable set of regulations for public and private users to deal with. By giving more attention to the preparation and technical backup for international negotiations, the United States would be in a better position to identify and defend its interests. In some cases, better technical information is likely to yield better international agreements, by removing misunderstandings about the effects of new technologies.

Earth Observations From Space

Civilian Earth observations from space encompasses a variety of space platforms, sensors and mission objectives, ranging from weather observations made by NOAA, to ocean observations and Landsat-type systems. The technology for weather observations via satellite has developed from the limited capability of the early experimental systems to a relatively mature technology. The relationship between NASA as the R&D and launching agency, and NOAA as the operational authority has also developed and matured over time. In general, this relationship now demonstrates how NOAA, as a lead agency with a clear mission to perform, can interact with an R&D agency, NASA, to stimulate and take advantage of advanced technology and adapt it to operational use (see ch. 9). The major areas of concern today are the Landsat and future oceanographic satellite programs.

For land remote sensing, the relationships between public and private interests are currently perhaps the most difficult areas to treat. The Carter administration, and now the Reagan administration as well, favored turning over this activity to private ownership and management, while the private sector, for the most pat-t, does not yet see a sufficient market to be able to respond. Caught up in the present uncertainty are the users of the data; a private industry of value--added companies that has grown up to process and interpret the raw sensed data, and the aerospace contractors capable of designing and building the satellites and other hardware. Complicating the scene are international pressures from a large number of other countries interested in using Landsat data (some with dedicated receiving stations); from a few countries planning the development of competitive systems; and from a number of countries with national concerns about the collection and use of remotely sensed data gathered about their territory.

policy options to resolve some of these issues include the following:

FOR THE SPACE SEGMENT

Laissez-faire or open entry. The Government would agree to operate space platforms through Landsat D and possibly D'. Further satellite systems would then become the responsibility of private industry. Government users would purchase data from private suppliers under commercial terms and conditions. Private suppliers would sell data to international users on a nondiscriminatory basis. Any private supplier or consortium (domestic or foreign) could purchase launch services and fly a land remote-sensing satellite. If the market did not support the service, it would terminate after Landsat D or D', except for possible DOD or foreign collection platforms.

With the current cost of launch services and satellites, there is only a very limited prospect that private sector suppliers would enter the field for the space segment. An important indicator is the nature of the current COMSAT suggestion that it assume responsibility for all operational remote-sensing systems.[24] They feel that the market is sufficiently marginal that transfer of all current operational remote sensing would (including meteorological satellites) be required, and the Government would have to commit to purchase its data from the COMSAT systems. Such marginal economics indicate very strongly that competition would not exist (beyond subsidized foreign systems) if COMSAT were allowed to proceed with its proposal. This would create a de facto monopoly, although in principle the prospect of open entry would be available. The de facto monopoly would continue until technology advanced to the point that reliable, low-cost access to space and low-cost platforms was available, thus allowing competitors to enter without the massive capital investments required today.

If the COMSAT initiative is not pursued, and other approaches are entertained through open solicitation of the industry, it is uncertain whether a single supplier (or even a consortium) would come forward to propose a data collection system without data purchase guarantees similar to those proposed by COMSAT. Thus, the likelihood is that a truly open entry policy would result in no entry.

Single designated entity. Whenever the service to be provided is such that the necessary capital investments are very large in relation to the industry base, and the technology and character of the system makes competitive suppliers either impractical or highly wasteful of resources, the conditions may warrant designating a monopoly supplier. A typical example was the designation of AT&T as the long-distance carrier for domestic telephone communications. With a monopoly supplier, however, regulatory mechanisms are required to control pricing and to insure continued service by the supplier. FCC carries out this function, as well as a variety of other important roles in communications. An important characteristic of the regulatory process must be the ability to change the monopoly situation to respond to new technological advances that modify the monopoly characteristics of the system. FCC has responded to such changes in the domestic telecommunications industry, although there has been criticism that it acted much too slowly.

On the premise that conditions may exist in land remote sensing for a monopoly supplier, ***one policy option would be to give a single private sector entity the role of developer and operator of the space segment.*** Since the revenue base for sale of the raw data does not appear adequate to support a positive return on the investment, the Government would also guarantee purchase of a minimum amount of the output, perhaps at subsidized prices, until costs and markets have developed to permit Government to decrease its role gradually. Because a monopoly position implies some regulatory control in order to protect the public interest, a new institution would probably be required to regulate prices, entry into the field, quality of services, and to control the amount and extent of Government subsidy.

The Civil Aeronautics Board (CAB) is a good example of such a regulatory agency. It originally regulated entry, controlled routes, reviewed

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[24] *Civil Land Remote Sensing Systems,* joint hearings before the Subcommittee on Space Science and Applications, House Committee on Science and Technology; Subcommittee on Science, Technology, and Space of the Senate Committee on Commerce, Science, and Transportation, July 22 and 23, 1981.

fares and revenues, and provided significant direct cash subsidies to the airline operators while the airline industry built its market and its ability to sustain profitable operations. The Government also guaranteed the purchase of services, in the early days with subsidized airmail contracts to the airlines, and later with Government cargo and passenger traffic. The rationale for treating this industry in such a special way is similar to the rationale that applies to land remote sensing, viz., there is a service to be supplied which would be highly beneficial to the public, and which could eventually become an independent and profitable private enterprise given initial subsidy. Because it is normal practice in our free enterprise system for the Government to use commercial suppliers, the Government should be prepared to act in a way that ensures continuation of the services while building toward a self-sustaining capability in industry. With the passage of time and growing industry maturity, the regulatory authority can decrease and eventually cease–as is the plan for the CAB.

This suggests establishing a new entity, which for purposes of this analysis will be called the Space Development Authority (SDA). SDA would have a role for new and emerging space applications very similar to CAB in air transportation. Since there are more opportunities than simply land remote sensing, SDA could function in all applications areas. It would control entry into data collection operations, initially establishing criteria for the monopoly supplier, and later permit greater competition as the market develops. It would review pricing of services and establish a fair rate of return using guidelines derived from other, similar regulatory situations. SDA might support this rate of return by adding a direct subsidy from appropriated funds. It would review proposed satellite configurations and establish, with the aid of the user community, minimum desired performance characteristics for proposed systems. The choice of technology, specific design characteristics, and award of contracts for hardware would be the responsibility of the monopoly supplier.

An important further consideration is the responsibility for advancing technology in order to continue improving the services provided and to improve the cost v. revenue relationship for these services. Here, the analogy with civilian aviation again illustrates a Government policy option. In aviation, the Government established the National Advisory Committee on Aeronautics (NACA) and its supporting laboratory structure over 65 years ago to improve aeronautic technology in the United States. The Federal Government still continues to support advances in aeronautics through NASA. The users of this technology are the military and civilian aircraft manufacturers, and the beneficiaries are the American public. Thus, a similar technology development role by Government might be appropriate in support of SDA, and desirable in terms of long-term benefits to the public.

Thus, *the NASA role as a technology "push" agency would continue, including definition and development of new sensors, platforms and associated subsystems, and supporting technologies such as launch vehicles, on-orbit control, tracking and data recovery.* This would be very close to the current situation with respect to R&D for meteorological satellites and the previous NASA role in the communications satellite area.

Establishing a regulated monopoly in remote sensing, although less desirable than true competition, can result in high-quality services and significant public benefit (e.g., AT&T and long-distance telephone service). A key characteristic of effective regulation is that it be as little as necessary in order to protect the public interest. In addition, the boundary between regulated functions and unregulated functions needs to be flexible in order to respond to changing industry dynamics and the effects of new technology. Therefore, SDA should operate under guidelines that specify minimal regulation and responsiveness to any changes that would allow for more open competition.

Adoption of the COMSAT initiative or one similar to it from another corporation or consortium would appear to require establishing a mechanism such as SDA. If not, the control over pricing would be difficult, and quality of service would be continually open to negotiation, with little in the way of alternatives open to the Government except canceling the agreement. There are additional questions regarding responsibility for performing R&D on advanced sensors (NASA or COMSAT, or both?), distribution of data by private companies and international access to the data, that would need to be resolved. These are not insurmountable, but they do raise doubts about the ability to anticipate and spell out all of the conditions for a transfer to a single designated entity that would protect the interests of Government and the public. Creation of an oversight and regulatory authority such as SDA would enable these issues to be addressed as they arise and would appear to be a wise precaution to accompany a policy decision to establish a monopoly supplier.

Government as the Operator. An alternative approach to the space segment, (consistent with the conclusion that a monopoly position is required, would be to retain the Government as operator instead of a regulated, private sector entity. In this alternative, procurement of the satellites, their operation and control, and the initial reception and distribution of the data stream would remain a Government function. Selection of system characteristics (sensors, orbits, number of satellites, type of coverage, and other parameters) should be done through consultation with the user community, and for this a formal structure is probably desirable. A Remote Sensing Users Group such as NOAA is now in the process of setting up would help ensure that users have an opportunity to participate in the planning of new systems and in the operation of existing platforms.

In this case the operator could be either the R&D and launching agency, NASA; an agency closer to a user community such as NOAA, USDA, or Interior; or a new Government entity established for this purpose that brought together several existing roles. NOAA will be responsible for overseeing the operation of the Landsat system after Landsat D is launched.

However, if a new agency were set up, for example, a ***Space Applications Services Administration*** (SASA) it could be responsible for defining, procuring, and operating satellites and ground stations and providing an assured flow of data from space applications systems. This agency would be independent of NASA and NOAA, but probably would include a portion of the existing space applications staff of both of these agencies. While publicly funded and hence accountable to Congress, it would collect user charges (like the recently disestablished Panama Canal Co., a former Government entity that was initially publicly funded but eventually became self-supporting). It would not conduct R&D, but would identify targets for NASA attention, and serve to channel to concerns of data users such as NOAA, USDA, and Interior in Governments; State and local governments; and private users (including private companies that process and interpret the data) to NASA. SASA would be organized to provide a valuable service at the lowest cost. SASA might assume responsibility for a variety of other space-related applications functions, such as meteorological and ocean-sensing data, storm warning, emergency communications, search and rescue identification and location, public navigation, and other noncommercial services. in this role it would be much like a private monopoly supplier, except for: 1) its status as a Government entity, 2) the fact that a separate regulatory entity would not be required, and 3) the periodic review of its operation that would occur through the annual budget process.

If NASA were given the role of space segment operator, the advantages would be: good integration with the present launch authority, assured technical competence, and substantial agency interest in the technology and its successful employment. On the negative side, NASA is prone to push the technology rather than its uses, and tends to continue experimentation rather than allow a system to become operational.

If it were a single established user agency, the problems would be somewhat reversed. The technical aspects become more difficult to manage and to integrate into the user's normal way of doing business; the format of satellite data is likely to conflict with previous ways of obtaining similar information, while the agency as a whole will not have much stake in the successful outcome of a satellite program that is only a small part of their total mission. On the other hand, there would be greater sensitivity to user needs and better contact with the user community (though quite likely not with all of the users in the case of multipurpose satellite systems). The satellite system would more rapidly become standardized and operational in this mode; once accomplished, new technology would probably be resisted unless “proven” and reliable.

In the case of a new Government entity created to assume responsibility for satellite applications systems, many of the above characteristics would be favorably modified, but other problems would be increased.

NASA would undoubtedly promote its mission by looking for, and attempting to satisfy demand for, new applications services. This would depend in part on obtaining support from NASA for technology development. By operating meteorological systems and Landsat, NASA might begin with a sufficient base to provide a critical mass for continuing operations.

GROUND SEGMENT

There are three areas to consider: 1) operation and control of the space segment; 2) reception and processing of returned data; and 3) distribution and interpretative processing of returned data. For the space segment it appears that use of NASA facilities on a reimbursable basis would be a sensible beginning. Independent control centers would be established as the business increased.

To receive and distribute satellite-derived information, current technology requires an array of unique and expensive equipment to convert raw returned data to images or other coherent forms. Since many users, such as agricultural analysts, require quick distribution of recently acquired data, there is a need for high throughput for the processing center and redundant equipment to allow for breakdowns or other system problems. Thus, for this segment, the potential exists for having a regulated monopoly supplier. This could quite logically be the same entity that was responsible for the space segment, in order to ensure compatibility of equipment and processing capacity as satellite designs and instruments change.

For the interpretive processing of returned data, on the other hand, an embryonic industry is already established, and continued open entry seems appropriate. Access to the initial processed data stream should remain open to all customers but at a realistic fee schedule, reviewed and approved by SDA. In order to protect the initial position of the monopoly supplier, it would probably be necessary to restrict competitive entry into the field of reception and initial processing of the satellite data stream.

As far as the space segment is concerned, a U.S. monopoly supplier appears to be necessary, at least for the foreseeable future. Competition is likely to be provided by one or more international systems capable of supplying similar data. (A more detailed discussion of international aspects, and policy options that respond to the growing capabilities of other nations, is found later in this chapter.)

The ground segment is as important to the total effectiveness of a remote-sensing system as the space platforms. The point is that providing adequate capacity for data handling and processing, compatible equipment, and common data formats should receive the same careful attention as the more glamorous and visible spacecraft. For this reason, it is important that the processing system be at least as responsive to user needs as to the R&D agency. If NASA were to assume responsibility for an operational remote-sensing system, there would need to be a stronger involvement by the users in determining the characteristics of the data processing system than is presently the case.

Space Transportation

Throughout this analysis the implied assumption has been that launch vehicles and their supporting systems such as launch complexes, tracking, and control facilities would continue to be available through customary channels. However, space transportation systems themselves may also be considered subject to possible new policy initiatives as defined in the beginning of this chapter.

For the most part, launching payloads into space has been sufficiently costly and complex that Government sponsorship has been required to develop and operate all but the most limited systems. As the cost and importance of payloads, civilian and military, have increased, it has also become particularly important to ensure that there is a high degree of reliability and a low probability of catastrophic failure. These concerns reach a peak when manned vehicles are involved; only the two space superpowers, the United States and the U. S. S. R., have devoted the resources and effort to carry out such operations.

In considering policy options for space transportation, therefore, it is useful to distinguish between the type and scale of operations involved, e.g., manned systems; large, unmanned systems to synchronous, interplanetary or low-Earth trajectories; small, low-altitude unmanned systems.

MANNED SYSTEMS

The presence of man in space has captured the imagination of people throughout the world, and has given national space efforts some of their most memorable moments. When astronauts are involved, there is always the possibility of a catastrophic failure leading to death or injury; such a disaster can have widespread effects on public opinion and hence on the future of the space program. The fire in the Apollo 204 capsule in 1967, which killed three astronauts, though it occurred on the ground, caused a lengthy delay in the Apollo flight schedule. The death of Soviet cosmonauts on reentry in 2 separate incidents in 1967 and 1971 had similar consequences. The result is that great care is given to the safety, reliability and resistance to single-point failures of manned systems. This also includes launch vehicles, which go through special procedures in order to make them “mandated. ” These special procedures are reflected in increased costs and in a sizeable support establishment for manned flight, both of which have been sufficiently large that only government has had the resources to conduct manned space operations. Only the United States and the Soviet Union have been willing to make the investments required to engage in manned flight, and this has resulted in a form of symbolic East-West competition, centered around such space endeavors, that rarely applies to the popular perceptions of unmanned space activities.

The development of the space shuttle has given the United States a launch vehicle that is simultaneously a manned system and a form of transportation for manned and unmanned payloads. The presence of man has focused public attention on its operations; it is viewed as another step in the continuing East-West competition in space, Recently there has been considerable discussion about the possibility of private ownership and operation of the shuttle system. For a number of reasons, this does not appear to be a likely prospect for the near term. One reason is the special political significance of manned spaceflight, as mentioned above. Although the frequency of operations envisioned for the shuttle—about one launch every 10 days–will result in the public devoting less attention to individual shuttle launches, and accepting man in space as relatively routine, it still appears likely that the loss of astronauts in space would be a major blow to national prestige. Given the cost of maintaining adequate launch, recovery, and refurbishment crews and facilities for the shuttle system, continued Government control and overall management seems likely.

A second factor is that, although each shuttle orbiter is projected to have a lifetime of about 100 launches, there will be a continuing need for system modifications and rework that are part of the standard experience associated with any new and complex system such as the shuttle. For these changes and continuing engineering support of the system, the resources of the Federal Government are likely to be needed—as well as the expertise of the major NASA Centers, Johnson (JSC) and Marshall (MSFC).

Third, the shuttle is planned to be the “delivery truck” for most low-altitude payloads, whether manned or unmanned, including national security as well as civilian or commercial payloads. The contributions of space systems to national security are significant and appear to be increasing; so it is not likely that the Government will wish to forego control over, and assurance of the availability of, adequate transportation to orbit. Direct Government operation of the shuttle and technical support for the shuttle system would be needed in order to provide the necessary assurances to national security authorities.

Fourth, there is the question of liability. The shuttle, in its launch configuration, represents a very high and concentrated amount of energy which, if it were to crash in a populated area, could have widespread detrimental economic consequences. Other forms of system failure could also be very costly from the standpoint of liability. Government is the institution most capable of handling such contingencies; although private insurance may be available to private shuttle operators, it would be another cost factor that would tend to limit private sector operation of the shuttle system.

There is currently a proposal by an investment group[25] for private-sector purchase of an additional shuttle orbiter. The proposal calls for this orbiter to join the Government fleet of shuttle systems, in return for which the consortium providing the funds would act as the sole shuttle payload marketing agents. The needs for continued Government control outlined above would not prevent such an arrangement, nor other innovative mixes of public and private investment. Such proposals should be viewed on their merits. It does not seem profitable to attempt to construct policies in advance that would adequately foresee all of the nuances of such proposed arrangements.

LARGE UNMANNED SYSTEMS

The transportation systems for a wide variety of sizeable unmanned payloads either to low- or high-Earth orbit or on trajectories beyond Earth orbit comprise the bulk of space launch vehicles for all nations and have been the source of greatest interest by nations that wish to enter the space business. As the basic technology that is needed for such launch vehicles is now quite widespread, the early near-monopoly by the United States and the Soviet Union is rapidly breaking down. The Japanese, the Europeans, the People's Republic of China, and India have all demonstrated their abilities to develop launchers, and other nations **could produce launchers if they decided to make such a commitment.**

For reasons described earlier, the United States has chosen to develop a manned system to launch large unmanned payloads. In the interim, work toward improvement of unmanned expendable launch vehicles has been minimal and there has been no new unmanned launch vehicle development. For a number of reasons, the cost of shuttle launches will be higher, and their availability less frequent, than was originally anticipated. All current U.S. expendable have also risen sharply in price, in large part because of the decision to develop the shuttle and phase out the use of ELVs. This appears to leave several "windows" in the potential marketplace for such systems. The major gaps are in the area of low-cost, relatively uncomplicated launches to low-Earth orbit and low-cost synchronous orbit emplacement of modest-sized payloads. It is to the second of these that the Japanese and European developments seem particularly well suited. In the United States, private investors are sponsoring work toward the former "win dow"[26] Low-cost space transportation, however, cannot attract much of a market if it does not provide reasonably high reliability, because the cost of payloads continues to be high. Hence, the willingness of a customer to entrust launch of a $30 million to $50 million communications satellite to a low-cost launcher will depend more on launcher reliability than on a small difference in launch cost.

Given the trend in alternative unmanned systems the United ***States could consider, as an option, developing a complementary, simple, reliable, and low-cost expendable booster that would serve to test the state-of-the-art in such systems and would act as a companion to the shuttle.*** Such a development could be carried out after a broadly based competition for the best ideas that would contribute to the dual objectives of low cost and adequate reliability. Such a program would be far more amenable to private operation, under appropriate safeguards, than would the shuttle. The launch vehicle options for the U.S. and international users would be expanded, and the U.S. would keep a valuable part of future space transportation alive and developing through this mechanism. "Competition" with

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[25] Craig Covault, "Firm Sets Down-Payment for Buy of Space Shuttle," Aviation *Week and Space Technology,* Jan. 18, 1982.

[26] See Statement of David Hannah in "Future Space programs: 1981, " hearings before the Subcommittee on Space Science and Applications of the Committee on Science and Technology, Sept. 21, 22, and 23, 1981.

Photo credit: RCA Corp.

RCA Saturn launch aboard a Delta launcher

the shuttle would be allowed, recognizing that the shuttle need not be used for all such launches.

SMALL UNMANNED SYSTEMS

There is a family of small sounding rockets and derivative systems that provide invaluable access to space for scientists with small-scale research payloads. These may be extended in capability for modest cost, and it would appear that open entry into this field should be permitted. However, here, as in the case of private launchers for low-Earth orbit, there is no policy in place for regulating such launches. Nor is it clear which Federal agency or agencies will be responsible for generating and enforcing the necessary regulations. In order to support industry's efforts to develop and launch its own vehicles it will be essen*tial to designate a lead agency to coordinate these efforts.*

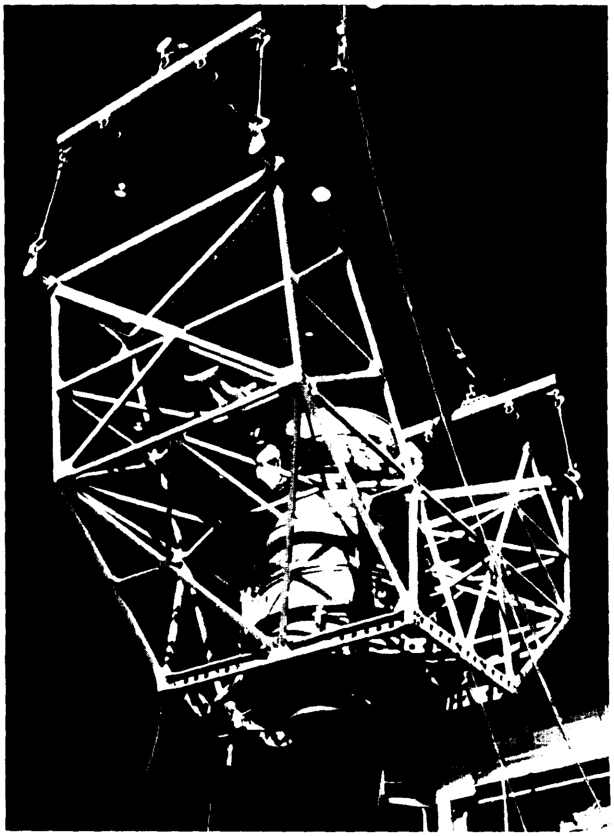

Photo credit: McDonald-Douglas Corp.

Payload Assist Module for use in boosting shuttle payloads to higher orbits

Applications R&D—Strengthening the NASA Role

As pointed out earlier, existing space policy identifies NASA as a performer of R&D for space systems, while remaining silent on operational responsibilities for the agency. The original NAS legislation says nothing about specific applications, and beyond maintaining U.S. leadership in space science and technology, there are few indicators of the pace of programs that might be generated. Thus, when the Nixon administration decided that the communications R&D programs of NASA were unnecessary and terminated the

Applications Technology Satellite (ATS) series, there was little basis for challenging that decision.

NASA does not lack the internal staff support for a more vigorous role in space applications. Such support could range from fundamental research to demonstration of sensors and integrated systems. However, there are other important internal claimants on NASA's resources, particularly the manned programs (shuttle, Spacelab) and space science programs (including planetary exploration). Consequently, the annual budget request for NASA is a compromise among the various opportunities for new starts (if any), the demands of each of the major agency programs for continuing baseline support, and the costs of prior-year commitments. The relative priority accorded space applications R&D may vary considerably in this setting, depending on NASA's management attitudes, the effectiveness of the internal advocates for applications R&D, and the urgency asociated with the applications areas involved.

The policy responses to these situations involve relatively minor adjustments to the existing framework, but despite their limited nature, they may be significant over time in generating additional attention to space applications needs.

The first deals with NASA's assigned responsibilities for space applications. One option is that space policy legislation recognize explicitly the continuing need for a program of fundamental research and demonstration activities in support of space applications. This would include advancement of technology in areas where the ultimate user is in the private sector as well as in Government. The rationale for such a posture is very similar to the argument used for Government funding of basic research and demonstration in fields such as aeronautics. Specifically, Government support may be appropriate when the risk is high, many of the benefits are nonappropriable, the time for potential benefits to accrue is long, and there are extensive potential public benefits. As such technology becomes suitable for incorporation in an operational system, the future operators should become responsible for the planning and engineering to utilize the new technology. judgments on where the boundary between Government support and private or user support lies must be made on a case-by-case basis, for each technology is different in regard to its operational adaptability and use. This issue, i.e., what it is appropriate for NASA to support, will therefore continue to be raised in the context of the annual budget preparations. The effect of a policy statement clarifying the existence of a NASA role will still result in debate on the extent to which that role requires, for example, a demonstration of a new technology on a satellite platform. Such demonstrations may be specifically allowed in the policy, but they would not be required. There will continue to be a need for considered judgment, discussion, and debate on such questions. This suggests a second policy initiative.

One of the important aspects of any space application is the user community. This community may be small and poorly defined for a newly identified or emerging application, or it may be very large and amorphous as in the the case of users of satellite weather data. Whatever its stage of development, it should always be possible to seek out and identify users and to have representatives become involved in a review of the NASA program in their area of interest (see ch. 9 for a discussion). Approval of particular applications demonstration systems could then be made with the aid of informed advice from the community affected by this work. ***NASA could be required by legislation to convene and support such user advisory groups and to include their reports as part of the justifications for the applications efforts proposed by the Agency.*** NASA has had such groups, but their role has been primarily internal to NASA. What is suggested here is a requirement that such groups report publicly to the Congress as well as to OMB. It should be noted that such user advisory groups would include other Federal Government agencies and State and local governments, as well as private members.

One additional policy option may be considered. In order to highlight the stature and importance of NASA's applications R&D efforts within the agency, and their prominence in dealings with OMB, it may be desirable to legislate an organizational change within NASA. Specifically, ***the applications programs could be made the responsibility of a Deputy Administrator of Applications, who would be in parallel with a Deputy Administrator of Operations and would have overall responsibility for planning, coordinating and implementing space applications research, as well as selected satellite demonstrations.*** This individual would support user advisory groups and—given the appropriate policy changes—could be responsible for operational systems within NASA's purview.

NASA's role in support of space applications R&D will continue to be uncertain, and funding levels will remain unpredictable, without more specific assignment of responsibility. NASA must take care to solicit and respond to the views of potential systems users; however, in cases where prospective users fail to recognize the potential of a new technology, or resist its introduction, NASA may need to promote the new technology actively.

International Aspects

part of the existing space policy of the United States is that activities in space will be conducted "for the benefit of all man kind," and one of the objectives of the U.S. space program is "Cooperation . . . with other nations and groups of the nations in work done . . . and in peaceful application of the results thereof." In international law, outer space is recognized as a nonappropriable area, analogous to the high seas, that is open to use by any state. From its very beginning, the space program has been directed toward foreign policy concerns and has recognized the inherently global nature of much that is done in space. This is particularly true for many space applications areas. Satellite systems that receive or transmit information have the capacity to serve a wide range of international users and to provide data about any part of the globe. Other systems, such as those for materials processing in space, depend upon the uniqueness of the space environment (e.g. microgravity) and are not inherently global in nature; nevertheless, since they would take place in space, outside the territory of any State, they would be affected by international laws and regulations. They have attracted the interest of several users other than the United States.

In the international arena, two major forces are at work—competition and cooperation (see ch. 7). In the early years of the development and evolution of space technology, the virtual monopoly on space technology of the two major powers made it both desirable and necessary for other nations to cooperate in order to gain access to space for scientific and applications purposes. As the technical sophistication of other nations has increased, some have developed an independent capability for designing and constructing satellites and launchers.

Though the United States as a matter of national policy has favored international competition as a device for improving goods and services and lowering their costs, there are circumstances under which this policy is modified, e.g., when a regulated monopoly supplier, such as INTELSAT, is established as described in earlier sections. Participants are required to plan national and regional satellite communications systems so as not to damage INTELSAT'S technical and financial integrity. The U.S. approach to international competition has been subject to additional constraints. For example, national security considerations would force the United States to restrict entry of foreign steel at the point where U.S. industrial capacity was being threatened. U.S. industry is also protected, in principle, against predatory pricing, "dumping," and other noncompetitive practices, in space, the U.S. policy toward satellite and satellite subsystem development, provision of services via space systems, and development of space launching capability has tended to favor, respectively, open competition, single systems, and nonproliferation of launch capability.

U.S. policy must recognize the competitive capabilities that already exist overseas, and the plans of several nations to initiate and continue the development of competitive systems. Where conditions warrant (such as when there are limited markets or problems with signal interference from competitive systems), U.S. policy may favor limiting competition by fostering a single global system, In other circumstances, such as meteorological observations, the united States has cooperated with other nations in the use of satellites for data collection, and the coordination of separately funded national systems. The exchange of information permits all participants to derive benefits that exceed the returns from a solely national system and at much less cost for each individual participant.

Telecommunications Services

In telecommunications, the United States supported single cooperative global systems for specific services and helped to establish INTELSAT and later INMARSAT. The U.S. position is based on the fact that economies of scale, the size of the international market, and the requirement for compatible reception and transmission of signals favor a highly integrated network with a single management structure. The situation becomes more complex, however, for proposed direct broadcast satellite (DBS) systems, in which the satellite distributes signals directly to individual receivers. The technical and political feasibility of such a system was demonstrated almost a decade ago with the United States- India experimental program (SITE) for providing educational television materials to remote villages using one of the U.S. ATS series. Such systems, which have been proposed by a number of U.S. and European entities, may threaten the existing structure of terrestrial broadcast stations and cable television distribution, and hence have been approached with great caution by the United States and foreign regulatory and communications authorities.

Direct broadcasting raises both domestic and international concerns about regulation of program content and competition with local programs. One of the principal worries is the transmission of signals beyond national boundaries, either because of unintentional “spillover” or intentional beaming of signals across international borders. These concerns have been debated at the U.N. and other international bodies for many years, without agreement on regulations for DBS systems. The United States has opposed restrictions on the international flow of information including those proposed for DBS. Severe limitations on spillover could create serious problems for the satellite system designer, for the shaping of ground patterns for signals broadcast from satellites is not a mature technology. Restrictions on transmitting across borders could affect the economic prospects for proposed DBS networks, especially in Europe.

For direct broadcast systems, many of these political and economic concerns are reflected in discussions of technical requirements, limitations on orbital spacing for geosynchronous satellites, and the allocation of frequencies. The major forum has been the International Telecommunications Union (ITU) and its periodic global and regional Administrative Radio Conferences. As in many other international bodies, the majority of the participating countries are not highly developed technologically, and this fact often makes it difficult to gain acceptance for new space services. It is also often the case that the technology associated with such services is ahead of the other necessary infrastructure to make use of the system, particularly trained technical and managerial personnel. Often, the resolution of ostensibly technical issues revolves around political conflicts between developed and less developed countries, Soviet bloc and Western states, and other such divisions. in such situations, the international regulatory process may require considerable clarification and debate about the industry structure, the sociological impacts, economics, and other key features of new service.

All nations, especially in the third world, share legitimate concerns about the availability of adequate electromagnetic spectrum for current and future services and, as pointed out earlier, information content and use of the spectrum for DBS systems. The space applications policy options that are to be considered should reflect these concerns, as well as U.S. public interest as a leading user and producer of telecommunications technology. The options tend to fall into two general categories, aggressive competition and broadened cooperation.

AGGRESSIVE COMPETITION

Many of the possible initiatives have been pioneered in this area by the long-standing practices that the united States has followed in helping to organize and extend the role of INTELSAT. Aggressive competition by the United States in this growing marketplace has been tempered by the necessity of gaining broad acceptance of and adherence to the INTELSAT agreements, and by the fact that, until now, the United States has been the sole supplier of most of INTELSAT'S hardware and managerial expertise. Political forces have necessitated more sharing of procurements and technology than might be the case in a highly competitive environment. Future developments under the broad umbrellas of INTELSAT and INMARSAT can be expected to be similarly constrained; competition for I NTELSAT contracts is likely to be more intense than in the past. However, there are new services that do not fall under these umbrellas and are being pursued by U.S. suppliers. These services involve purchases of ground or space hardware that are needed for a foreign system, via a solicitation that is open to any qualified supplier.

One principal area of concern has been the difference between U.S. practice–which calls for the rigorous application of antitrust provisions to any U.S. firms intending to bid—and that of our overseas competitors, where there is often a high degree of collaboration among Government and various industry suppliers. Hence, if we were to adopt a policy of "aggressive competition" in this area, it would imply that *U.S. policy on antitrust restrictions and restrictions on other forms of information exchange for space communications would be relaxed in order to encourage joint ventures by industry the better to exploit the U.S. technology base.* This plan could be accomplished by encouraging industry to take advantage of a procedure already available in the Justice Department Antitrust Division to render prompt advisory opinions in response to industry requests to work together on such projects. This would have the effect of strengthening the U.S. position vis-a-vis our overseas competitors.

Another possibility is expanded collaboration with overseas firms. One issue that results from such collaboration is: How to guard against the possibility that technology transfer between the United States and foreign partners may enable them to become more competitive on subsequent contracts? U.S. suppliers have a great deal of technological know-how as a result of a broad set of space and telecommunications developments, both publicly and privately funded, over the past 20 to 40 years. Other nations have highly skilled scientists and engineers similarly engaged, although generally not with the same level of space systems experience. For specific technologies, e.g., reliable, long-life, high-power traveling wave tubes, U.S. suppliers may find that they can benefit from technology that exists overseas. [n other areas, such as total systems design, the reverse may be true. In some cases, cooperative ventures with overseas firms may be desirable for political reasons; for instance, in negotiating the contracts for the recent sale of equipment and services to Arabsat, a communications satellite consortium consisting of a number of Middle Eastern countries, Ford Aerospace could not be the prime contractor because of its position on the "Arab blacklist" for having dealt with Israel. Ford then became a subcontractor (although receiving a majority of the value of the contract) to a French firm, Aerospatiale, which took the lead in negotiations.

For a number of reasons, U.S. policy has favored limited duplicative launch vehicle developments, but this policy has not been strongly pursued. Both technology transfer from the United States, as in the case of the sale of Thor-Delta technology to Japan, and indigenous developments such as the European Ariane vehicle, have resulted in the imminent availability of capable, yet relatively low-cost foreign launch vehicles for applications payloads that are competitive with United States and Soviet systems. Thus, we are at the threshold of a period in which "aggressive competition' will probably be practiced by others, whether or not the U.S. policy favors such a posture.

BROADENED COOPERATION

The growth in foreign technical capabilities, their aspirations for a greater market share for their industry, and their desire to have more independent control over development and deployment of space systems for their own use have changed the space applications outlook. The existence of an independent launch capability is particularly significant in this regard, because it permits a great deal of flexibility in placing competitive national or regional systems into orbit and in providing a variety of specialized services.

In the communications realm there would appear to be little prospect of a near-term threat to INTELSAT'S long-distance and overseas markets from independent launch of satellites for general purpose communications because of the size and sophistication of the INTELSAT system and its expected ability to keep pace with technology. For INTELSAT and also for INMARSAT, it appears that no U.S. policy change is needed. With regard to a foreign nation's internal communications systems, current U.S. policy recognizes that this is an internal question for the specific nation, and—given that it constitutes no violation of other international agreements—would launch or otherwise support such a system in accord with established principles regarding foreign cooperation.

A possible future problem for INTELSAT may come from the proliferation of regional systems such as Arabsat, Nordsat, and others. A policy of "broadened cooperation" would entail a strong U.S. effort to bring such systems under a cooperative umbrella. The basis for this policy would be both economic and technical. Economically, it would be advantageous to use the larger-scale requirements already embodied in INTELSAT to provide additional service extensions for those nations able to use the large-capacity ground stations currently needed for system compatibility. For nations with limited internal communications infrastructure, satellite systems designed to operate with smaller and much less costly ground stations are attractive. The technology for these systems has been demonstrated and several such systems are planned or in operation, and U.S. policy might be to help extend this type of service to a much wider number of potential users. The mechanism for this could be a separate subdivision within INTELSAT (for specialized services) or a new cooperative international/ enterprise. In both cases, the basic objective would be to provide multiple small users access to high-quality communications services that are more compatible with a limited local infrastructure, and with a limited ability to invest in ground station capacity. The system would be optimized for low-capacity ground stations and would make maximum use of the spectrum through multiple spot beams, "on-call" service, and other techniques appropriate for low-volume users. In principle, any nation should be able to obtain satellite communications that are matched to its particular stage of development, economic needs, and the density of local communications infrastructure.

By providing leadership in identifying the specialized needs of smaller nations and translating these into technical specifications for communications services, the United States can accelerate the process whereby space communications can be readily provided to all nations. By bringing these multiple small users together, the aggregated market should be capable of supporting appropriate satellites. This would tend to reduce or eliminate the need for ad hoc groups of nations to organize independent regional systems. Consequently, greater technical compatibility would be ensured, and there would be greater likelihood of continuing technological advances to improve and broaden the services provided. The proposed entity would be analogous to a local telephone system, connected through a switching system to a larger network, but providing individual lines to many small subscribers at the local level.

Land Remote Sensing

Remote sensing from space has inherent international ramifications because the vantage point provided by the orbiting space platform provides broad synoptic coverage that is not limited to national boundaries. In contrast to the international cooperation that is essential for a successful global communications system, remote sensing does not require direct cooperation to be successfully pursued—although cooperation in providing "ground truth" information is very useful, and foreign ground stations collect data that would otherwise be unavailable. The fact that cooperation is not essential has allowed Earth remote sensing to develop without a clear, international framework that would deal with such questions as rights to data, maximum resolution limits, technical characteristics of the sensors and platforms, data format, orbits and repetition rates, and a host of other policy and operational questions.

In approaching the international aspects of remote sensing, the United States has been guided by several principles: 1) overflight of a nation by an orbiting satellite should not be prohibited, assuming other treaty obligations are fulfilled; 2) the civilian remote-sensing program should not give rise to negative reactions that might constrain military and intelligence uses of space platforms; 3) cooperation with other nations is encouraged; and 4) data collected are to be made available to any interested party on a nondiscriminatory basis, for a fee. The early flights of the Landsat series of satellites resulted from unilateral decisions of the United States; international aspects were incorporated largely as byproducts of the effort to generate users and develop a better understanding of user requirements. Consistent with the principles listed above, the data have been been made available widely on a nondiscriminatory basis, Earth stations have been sold to enable other nations to collect data directly, and careful choice of resolution limits and sensor performance characteristics has caused many of the early concerns about Landsat as a spy in the sky to dissipate. in the interim, the United States officially revealed its military reconnaissance satellite program—confirming what most observers already believed–so that, at least publicly, the role of Landsat and its follow-on systems could be more clearly addressed in the international arena.

The United States clearly had a significant lead in civilian remote sensing—almost a decade ahead of Soviet and emerging European and Japanese systems. With the passage of time and the lack of a clear U.S. commitment to maintaining an operational Landsat, the development of competitive systems such as the French SPOT was a logical consequence. Some policy options available to the United States before the French decided to proceed with SPOT may now be foreclosed by its existence; they will at least be significantly modified. In general, the policy options fall into three categories: aggressive competition, laissez faire, and expanded cooperation.

AGGRESSIVE COMPETITION

It may be assumed that U.S. technology, including what is available from national security systems, would permit significant improvements in ground resolution, and that multispectral sensing could be provided at adequate resolutions and at appropriate wave lengths, on a timely basis, for international as well as national use. Therefore, it is likely that anything other nations may choose to provide via an Earth-sensing system, could be matched or improved upon by the United States if there were adequate budget support and commitment. It should be kept in mind that any U.S. system will have to compete with SPOT and its derivatives, whose products are not likely to be priced to reflect their true cost. Political considerations of national prestige and advancement of high-technology enterprises may transcend questions of cost recovery. In short, aggressive competition is not likely to cause systems like SPOT to be discontinued, although it may make such investments less profitable.

The implications of aggressive competition appear to favor a continued role for Government as the operator of the space segment, but with a clear commitment to operational status for the system. This commitment would assure continuity of data, adequate processing capacity to insure timely availability of data to international as well as national users, and an active R&D program to support system improvements.

Pricing of products would be competitive with alternative systems. The premise would be that the overall global and national benefits, particularly the nonmonetary ones, would justify the subsidy to this system. Examples of the latter include the goodwill that would accrue to the United States from use of data forewarning crop failures, severe storms, or other hazards; post-disaster monitoring; monitoring the global biomass inventory; monitoring the status of the ozone layer and other worldwide environmental phenomena.

LAISSEZ FAIRE

As an alternative, the united States could also turn over responsibility for operational systems, if any, to the private sector and buy the data it needs from whatever source was most appropriate—including foreign systems. Government users might be able to obtain appropriately screened data from classified systems, but the principal sources of remotely sensed data would be commercial suppliers. The market would determine pricing and availability, and Government would be precluded from direct competition with the private sector. This posture would not foreclose a continuing R&D role for NASA, but would require that any operational system be developed in the private sector. Satellites that serve to demonstrate a sensor or system could be Government funded or might be jointly supported. Pricing of products would be set by the private supplier, perhaps with Government participation. Because it can be expected that foreign systems will be subsidized, a private U.S. operator may have difficulty competing unless the Federal Government provides equivalent support. if industry did not see an adequate market for remotely sensed products and did not purchase a satellite, there would be no operational U.S. system, and U.S. users would have to seek other means of obtaining their data.

BROADENED COOPERATION

Alternatively, the United States could seek to extend the arena of formal cooperative arrangements to include ocean and land remote sensing. Under such broadened cooperation, the pattern established under INTELSAT would be adapted to the remote-sensing field, For example, it should be possible to define a single management authority that would assume responsibility for global operational systems, establish technical specifications, procure satellites, and operate the satellites and the initial data reception and processing facilities.

In order to make such a new international entity possible, participating nations would be expected to forego launch and operation of national systems for civilian purposes. This would not preclude national R&D on sensors or platforms; but such systems could not substitute for commitments to the global consortium. Successful R&D could be integrated into the global system under a negotiated arrangement. Basically, the United States would be proposing to join together with other nations in launching and operating a common set of data collection platforms, with revenue to be obtained from the sale of raw or processed data. The returned data stream from the common operational platforms would be encoded so that only consortium members would have direct access to the data. Others would be able to purchase data from the central organization at established prices. The rationale for this approach is based on the following.

- Market. -the current limited and uncertain market for these data makes competitive systems redundant, and is not adequate to support a commercial operator.
- Interest.—There is broad international interest in such systems.
- *Competition.* –It is too late for the United States successfully to preempt foreign competition by offering greater or more favorable access to future Landsat data.
- *Cooperation.*— By joining together, large and small nations can participate in the benefits from a common global system with less fear of exploitation by particular nations or private firms.
- *Globa/ systems.* –This approach would facilitate global monitoring systems for critical environmental factors such as forest inventory, biomass, carbon dioxide and ozone concentrations, which could be operated as joint projects by the consortium.
- *Economies of* sca/e.–Economies of scale could be achieved by common use of Earth facilities and data processing facilities to serve multiple customers, and lower cost satellites. These advantages are similar to those that INTELSAT enjoys in its multiple-satellite purchases.

The initial startup period for the consortium could be handled in a way very similar to the INTELSAT model, with interim agreements in force for a fixed period during which the detailed operating practices would be negotiated. Some of the current practices that are followed in the communications area could be expected to carry over to the global satellite consortium, including procedures for procuring operational satellites, contracting for launch services, and establishing satellite control facilities. The ground processing of data is sufficiently complex and sensitive (particularly control of decoding) that the initial stages should probably be a consortium responsibility, rather than being handled by individual governments, with subsequent interpretation made by other entities, either government or private sector. For the purposes of this assessment, such a consortium will be called "Globesat."

The differences between communications and remote sensing need additional comment. Communications *requires* active cooperation, remote sensing does not. Any alternatives to a global cooperative entity such as INTELSAT still require agreement and compatibility between separate states. The alternative to Globesat, however, is completely independent national collection platforms. Communications involves a shared benefit between the linked points, while the sensed data from an observation satellite are primarily of value to the controlling authority or to entities who use the data for specific purposes.

Privately owned international communications have, for the most part, minimal national security implications. Conversely, increasing resolution for satellite observations leads inevitably to national sensitivities regarding the detection of military installations, troop or equipment deployment, and other sensitive information. Globesat would provide a forum for reaching common agreement on system specifications and could serve to alleviate sensitivities on the part of participating nations regarding the nature of civilian remote-sensing data that would be available regarding their country. Using encoded data streams would allow selective processing so that it would be possible to limit access to high-resolution data from a particular nation if that nation required imposition of such limitations. It can be expected that most nations would avail themselves of this privilege, charging a fee for foreign or private sector access to high-resolution data. Alternatively, it could be Globesat policy that a nation could restrict access to high-resolution data for a fixed maximum period of time, say 6 or 12 months. This would reduce sensitivity about military movements and would enable national interests to have the first opportunity to use the data. As pointed out earlier, U.S. policy has been to gain acceptance of "open skies" and "open data" policies; restrictive actions carried out under Globesat might appear to undermine these positions. However, the basic concern of U.S. policy, that is, the principle that there shall be open access via satellite systems to co//ect such data, is not infringed by the Globesat practices suggested above. It is simply the civilian use that is being controlled, if specified by a participating country, and this use would reflect legitimate economic interests that the United States also shares. Thus, it appears that Globesat could operate in a fashion that is both consistent with longstanding principles of U.S. policy and yet respect the valid concerns of other participating nations.

Is it possible for Globesat to function under the auspices of the United Nations? There are organizations, such as the World Health Organization (WHO) and World Meteorological Organization (WMO), that have successfully overcome some of the inhibiting characteristics of such broad sponsorship. However, it would appear that Globesat is not suitable to a U.N. format, at least in its formative stages. The large number of competing interests, coupled with fears of exploitation, would likely make reaching agreement on a system very difficult. The overwhelming difficulties that the Law of the Sea Treaty has faced are a case in point. Transition to a U .N. relationship would be an issue for consideration at some future time. In 1978 France proposed, at the U. N., that a remote-sensing agency be established to monitor worldwide military activities and disseminate information to all countries, thereby forestalling aggression. If such a plan were agreed upon, Globesat could be the appropriate entity to operate the system.

A major concern in a system with multiple owners and users is the adequacy of data collection to serve user needs. Telephone, television, and digital data are the principal components of international communications traffic, and common systems can be designed to fit a variety of such users. For Earth observations, however, satisfying user needs is not as simple; the users are not well organized, and their data needs are not standardized or well understood. In addition, the most desirable observation times, frequency of observation, and spectral bands differ from user to user. Hence a difficult set of compromises would be required to establish the satellite system specifications. Combining several sensors on a single platform would be traded off against the advantages of multiple platforms with fewer sensors. Presumably sensors such as those planned for SPOT and Landsat would be candidates, as well as others that may originate elsewhere. In Globesat, the united States would have no guarantee that the compromises would satisfy U.S. needs; however, because the united States would be a major user and source of revenue, it is likely that these needs would be given some priority. There is also no guarantee of continuity of data, but there is no guarantee of data continuity for strictly national systems, either. It seems probable that an international consortium such as Globesat, with broad user and national support, would have a greater commitment to continuity than would be the case for a single U.S. supplier.

The adoption of the Globesat option would imply that several policy options defined earlier would become impractical. For example, creation of a single national regulated satellite operator for U.S. remote sensing would be counter to the principles upon which Globesat would be based; Globesat would substitute for the U.S. operating entity. However, there would be a need for a U.S. representative to Globesat that would reflect the views of various U.S. users. This representative could be a designated Government agency, and existing group, or a new entity that would have responsibility for distribution of U.S. data, as well as coordination of the various user community needs.

An important unknown in considering Globesat would be the position of the Soviet Union. The Soviet Union has operated remote-sensing satellites for many years, and recently announced its intention to provide a “continuous-look” system similar to Western satellites. The Soviets could use such a system to compete with Globesat; alternatively, if they were to join, the difficulties of agreeing on system specifications and operating details might be much greater.

In summary, many of the international concerns about remote sensing could be suitably accommodated within a global consortium that could also fulfill U.S. needs. At this point, it may not be possible to obtain international agreement on such a structure because of the prolonged period of U.S. indecision regarding remote sensing and the resulting efforts by other nations to satisfy their needs through independent systems. It would take a strong U.S. commitment to Globesat for such an entity to be initiated and established.

Economic Measures

One of the common characteristics of space applications systems is the high entry cost associated with the development and institution of new systems. The principal hurdle has been the high cost and difficulty of transporting the satellite to its proper orbit. A large additional cost results from the absolute necessity for extremely high reliability for the payload, which must function for long periods of time without maintenance or repairs. Complicating factors are the environmental stresses: the shock and vibration of launch, and the vacuum, low gravity, alternating heat and cold, electromagnetic radiation, and solar wind of space. The net result, given the small numbers of satellites actually flown, has been that virtually each satellite has been a new and delicate design requiring its own set of tests.

[t is possible that routine and reliable access to space via the shuttle and the availability of astronauts to perform tasks such as replacement of wornout parts, repairs, or fueling could lead to an era of less costly satellite platforms. As part of the shuttle program, many of these concepts will be explored, including developing a common spacecraft bus that would provide standardized housekeeping functions needed for all satellites, such as command and data links, power, attitude control and station keeping. In addition, NASA has offered small amounts of shuttle payload bay space at very low cost, the so-called getaway specials, for small experimental packages. But these are only the first steps along the road toward lower cost access to space, and it is not likely that significant change will occur, at least in the next decade or so. Satellite maintenance is severely limited by our inability (even with the shuttle) to transport men into geosynchronous orbit, where most communications satellites are located. Thus, although steps are being taken that could lower the high cost of satellites, this will remain a significant barrier to commercial entry into space applications service areas.

Beyond the direct cost of the satellite, there are additional costs for the construction and operation of ground facilities to link with the satellite. Communications and remote sensing require extensive satellite control facilities, ground receiving stations, and data processing systems. Materials processing in space is relatively free of such costs.

With such significant entry costs, private sector involvement in space applications has been limited (see ch. 8). Government policy has served as a primary stimulus for such involvement, primarily in communications, through regulation, joint Endeavor Agreements, and congressional actions such as the COMSAT Act, the National Aeronautics and Space Act (for R&D), and INMARSAT legislation. If there is to be a new thrust to open space applications for commercial exploitation, the economic barriers to entry need to be addressed. Several approaches appear feasible.

Space Development Bank

Government has used the device of a development bank or system of loan guarantees to finance socially desirable objectives in a wide variety of settings, from international development (World Bank, Interamerican Development Bank) to sale of U.S. products (Export-import Bank) and U.S. housing (Federal Housing Administration and Veterans Administration loans, Federal National Mortgage Association, Farm Credit Administration, Federal Home Loan Bank System). More recently, loans or loan guarantees have been used to make a college education more accessible, to prevent the collapse of major corporations (Lockheed and Chrysler), and to provide incentives to small business. Thus, a determination by the Congress that the growth of space applications was socially and nationally desirable and that the preferred approach was to keep such growth as much as possible in the private commercial sector, would open the possibility of establishing a Space Development Bank (SDB). A similar concept, the Space industrialization Corporation (H. R. 2337), has been the subject of recent congressional hearings. (A more detailed discussion of this specific piece of legislation can be found in chapter 8.)

The role of SDB would be to: 1) receive proposals for space applications investments; 2) evaluate these applications; 3) if acceptable, provide funds at preferential loan rates and establish a deferred payback schedule; and 4) monitor the progress of the business plans on the basis of which loans have been made. SDB would require initial authority for drawing rights upon Treasury funds appropriated for this purpose, but in the long term the SDB would be self-sustaining and pay back the initial appropriations. SDB would provide an initial subsidy to qualified entrepreneurs, with the amounts and areas to be determined by negotiation and the developing marketplace.

SDB could also provide incentives for private entities to form joint ventures for specific services for which a single supplier was not available or appropriate. As such, SDB could act as a quasi-regulatory body, controlling entry into space applications fields to maximize social benefit. (It should be recognized that there are limitations to this role. For corporations like COMSAT, with a continuing statutory role in space applications and a large and growing revenue base, entry into new space applications services would not depend on incentives such as SDB would provide. An expansion of COMSAT into other areas, particularly remote sensing, would create—de-facto–a commercial space applications monopoly. As explained earlier, the public interest would likely require that such a monopoly be accompanied by a Federal regulatory authority.)

SDB, on the other hand, would be associated with more open entry. The provision of capital at low rates would serve to attract a broad array of potential suppliers, and a separate regulatory body may, therefore, not be needed.

Tax Incentives

The tax incentive is another governmental device used to promote socially beneficial actions. It is currently being employed to encourage R&D generally, to stimulate energy conservation and use of solar energy, and to encourage investment in new plant and equipment. The advantage of the tax incentive is that very little additional Government manpower is needed to administer its provisions—and the decision making is almost completely free from Government management and, therefore, more nearly reflects the realities of the marketplace as it is understood by the private firms.

INTEGRATED POLICY OPTIONS FOR SPACE APPLICATIONS

The previous section outlined a number of individual policy options to address specific issues. In this section, the policy options will be grouped into larger patterns or themes to give a more integrated picture of the range of options available.

It should be recognized that the grouping of policy options presented in the following material is illustrative and may be modified by the addition or deletion of specific elements. The options are not necessarily exclusive of one another. They are presented in this integrated fashion to give a better understanding of the types of actions that may be contemplated and the relationships among the various policy elements.

Continuing the Current Policy Framework

Current policy, as expressed by the existing legislation, permits a great deal of flexibility to organize and conduct a strong space applications program and gives implicit authority to Government, not only to conduct R&D but also to operate systems. There is, in addition, wide latitude to assign specific tasks to agencies and to permit private-sector participation in essentially any phase of activity. Thus, the role of the private sector in remote sensing could be expanded to include operation of space and ground segments simply by Administrative action. (Transfer of ownership of existing satellites systems, which are Government property, would require separate congressional action.) The policy framework for space communications is also flexible and permits both Government and private sector roles in a wide range of services, subject to FCC and ITU regulations. The specialized position of COMSAT is defined in legislation and therefore restricts the choices in this area. In transportation and materials processing, there is similar flexibility with respect to the institutional structure and the extent of the private role.

Continuation of the current legislative framework permits policies ranging from strong Government leadership and participation to a laissez faire approach in which Government stands aside and explicitly invites private groups to assume a larger role, without emphasizing or requiring any one approach.

While there is a wide latitude permitted by the current policies, there are no clear goals, no timetable and no overall direction for space applications. As a result, it is difficult for the Government to identify and pursue the benefits of space applications.

If nothing is proposed beyond current policy and practice, neither the U.S. private sector, the Government, nor the public at large will benefit fully from the country's large space investments over the past 24 years. U.S. leadership in many areas will be lost. Viewed in an historical perspective, such a course would raise serious questions about our ability as a nation to pursue long-term objectives when faced with short-term problems.

Increasing the International Emphasis

A number of policy options hinge upon the approach that is adopted toward international competition and cooperation. This approach suggests a strategy that may be termed "international emphasis." Under this approach, the United States could adopt a general guideline; i.e., "all *inherently international civilian space applications should be carried out on a cooperative international basis, and be the subject of an agreed institutional framework.* " If this approach were followed, we would pursue the establishment of an entity like Globesat for remote sensing and a new communications satellite structure that would vigorously develop the market for small, low-volume users. U.S. needs would be met by these entities, as appropriate; as a consequence, questions of private-sector entry and foreign competition would become moot–given that the necessary international entities were successfully established. The United States could designate COMSAT and/or other entities to represent it in these new international bodies. Other applications such as transportation and materials processing are *not* inherently international and would therefore be treated separately. NASA would continue to do R&D on new technology, but on a much more limited basis. It might also do some development work under contract with international organizations. The requirements of U.S. users would need to be identified systematically and formally in order to provide adequate, timely specifications for Globesat and other entities. Responsibility for convening such groups and incorporating their needs into U.S. positions in the appropriate international bodies would reside with the chosen U.S. representative.

A policy with an international empahsis is attractive because it tends to clarify so many other related aspects of the policy picture. It has the effect of moving operational responsibilities out of the U.S. Government, via an international quasi-private entity, and thereby reducing direct Government expenditures for such systems. It is consistent with U.S. policy in communications, in which we have strongly supported a single global system via INTELSAT and INMARSAT. [t clarifies the issue of international competition in remote sensing by creating a strong incentive to participate in the common, i.e., Globesat, system.

This option also carries with it a number of risks or limitations. The outcome of such a U.S. initiative on the international front is problematic. Sovereign nations will tend to protect their interests and seek advantages in this area as in many others. It would therefore require considerable care in outlining the advantages of a common system (or systems, e.g., using SPOT as well as Landsat technology) and in creating strong incentives for the principal initial partners to join with the United States. Though the optimal moment for this proposal has probably passed, there is still an opportunity to create a common entity—if the United States moves promptly and decisively. Another aspect of this approach is that it implies some loss of independent action on the part of the United States. We would be (as in INTELSAT) foregoing our own independent systems in favor of a cooperative international effort. Arriving at an agreement among the international participants regarding the number of satellites, their sensors, data formats, and other operating characteristics, as well as the procurement guidelines for equipment and services, may be a difficult and prolonged task. The procurement guidelines can be expected to result in mandatory sharing of the development and production tasks among the participants and, hence, a possible reduction in U.S. contracts as well as sharing of U.S.-developed technology with overseas firms.

Finally, the reality of the growing independent space capabilities of other nations means that they will eventually be able to carry out such a plan without U.S. participation, if they choose. Although such a prospect is not likely in the near future, other data collection systems will be launched, if Globesat is not established, each of which will compete for a limited market. The alternative of a common system has strong economic and political advantages.

Increasing the National Private Sector Role

The approach here would be to extend the current U.S. practice of maintaining an independent data collection system, but one that gives the private sector a stronger role in specifying the system and the method of operation on. The basic principle would be: "/t is *U.S. policy that the private sector own and operate space systems. "* There are several basic approaches:

- ***Open entry.*** —This would involve encouraging multiple suppliers to provide services. Incentives would be offered via tax breaks, loans, and other financial aid via an SDB; in addition there might be guarantees of Government data purchase, no Government competition, and measures to preclude a monopoly supplier. In communications, the conditions for regulated, open entry have already been established.

- Private monopoly.—This alternative applies principally to remote sensing. In this case, the entity could be an already established corporation, or a new public-private company. Ground-segment ownership would follow the choice for ownership of the space segment, as explained in an earlier section. The choice of a private-sector monopoly supplier would be accompanied by establishing a regulatory body.
- Government rnonopoly. -Continuation of the current Government monopoly for the space segment would be possible, with increased private-sector participation in the ownership and operation of all the ground data reception and processing stations. This recognizes the currently limited marketplace and the need for continued Government support of operations to ensure maximum public benefit from space applications, particularly remote-sensing systems.

Because this approach is principally an extension of current policies, though increased emphasis is given to the role of the private sector—a point of view strongly supported by the Reagan administration—it probably would be the easiest on which to develop a consensus between Congress and the executive branch. But a national consensus does not necessarily lead to a satisfactory resolution of all the issues, particularly in view of the degree of sophistication and independence found in other nations today. The United States can attempt to meet this competition and continue its own independent developments, including increased private-sector involvement, or it can seek a collaborative and cooperative framework as outlined in the previous section. If we choose an independent course, additional policy questions arise, such as whether U.S. private firms and/or the Government will buy data from foreign systems. The approach outlined here is consistent with a policy that would permit purchase of data from a foreign system by private users without restriction, but subject Government users to whatever purchase agreements had been negotiated with a private U.S. supplier (or suppliers).

Increased High-Level Policy Focus

Spanning the range of all of the above approaches, there is the suggestion that both current and continuing developments in space policy would profit from increased high-level attention in the executive branch and Congress. There are several approaches that may be taken to accomplish this increased high-level review and decision on national space policy. They are all compatible with the various policy options discussed in the preceding sections. The premise on which they are based is that space policy is sufficiently important to warrant greater attention from both the executive and legislative branches of the Government.

The policy directions set by the different approaches above would require attention by the administration and Congress in the form of implementing guidelines, program direction, and budget decisions—in short, of continuing followup over a number of years. International initiatives, if adopted, must receive high-level endorsement and be integrated into the overall foreign policy stance of the United States: the responsibility to implement such initiatives cannot be left to a single agency. Thus, whatever new approaches are taken, they should be matched by suitable steps to strengthen the process of developing space policy. Without such a step, the other measures are likely to be less than adequate in meeting the many needs identified in this assessment.

APPENDIXES

Appendix A

INSTITUTIONAL EVOLUTION OF THE U.S. SPACE PROGRAM

Introduction

This section focuses on the relationship between space policy and the institutions of the space program. It traces the origin and evolution of the institutional structure of the U.S. Government for civilian space activities, and it asks whether that structure, as it exists today, is appropriate to the kind of civilian space program the United States has today and will have in the near future. Institutional effectiveness is a means to the success of certain policies, not an end in itself. On the **other hand, a mismatch between policy and structure is likely to be a major barrier to such success, and thus an issue deserving** of detailed attention.

Not infrequently in Government programs, particular policies reflect the requirements of a particular institutional structure. As the subsequent discussion will suggest, there is not much evidence of this being the case with respect to the civilian space effort. It seems, rather, that for space, the relationship is as most students of public administration would have it: that is, structure follows strategy. In the U.S. space programs, institutions to a large degree have been based on and designed to implement agreed-on policies and carry out particular programs, rather than the reverse relationship.

What follow attempts to demonstrate how the basic policy principles were translated into a particular institutional structure, and how that structure has evolved since its inception. It does not purport to be a definitive description of the institutional structure of the U.S. space program or of its evolution over the last two decades. Rather, it highlights those characteristics of and relationships among structures that appear relevant to any evaluation of the current and future organization of the national space effort.

Separate Programs, Separate Structures

The policy decision with the most direct impact on the structure of the U.S. space program was that calling for the institutional separation within the Government of the civilian and military space activities (see ch. 6). In the immediate post-Sputnik period, when it was evident that some accelerated response to the Soviet space accomplishments by the United States was required, there were a number of contenders for the job of managing the national space effort. they included:

- a single agency for all Government space programs managed by the military, either at the level of the Secretary of Defense or by one of the armed services, most likely the Air Force;
- a new Cabinet-level Department of Science and Technology which, among its other responsibilities, would have charge of the civilian space effort;
- adding space to the responsibilities of the Atomic Energy Commission;
- expanding the responsibility of the National Advisory Committee on Aeronautics (NACA) to include a substantial component of space activities; and
- creating a new civilian agency with a responsibility for Government space activities, except those primarily associated with defense applications (which would be managed by the Department of Defense (DOD)).

Once the decision to separate civil and military space activities was made, the claims by DOD and by the armed services that they were the appropriate managers of the national space program found limited political support either within Congress or in the public (outside of those constituencies with close connections to the military). The idea that the U.S. space program in its civilian aspects should be an open, unclassified effort was widely accepted among those concerned with shaping national space policy.

As the Government agency concerned with aeronautics research, NACA mounted a campaign to have space added to its activities. However, NACA was an introspective, research-oriented agency with little orientation toward major technological enterprises. Further, it was an agency managed by a committee, not by a single executive; this was an administrative arrangement strongly preferred by the scientific community as a means of insulating Government activities with strong scientific components from “politics. ” A similar form of organization had been accepted for the **Atomic Energy Commission and had** been proposed, but vetoed by President Truman, for the National Science Foundation. What Eisenhower’s administrative, **budgetary, and policy advisers** wanted was an agency responsive to the policy directions of the President, headed by a single individual responsible for implementing those policy directives, and with the capabilities for carrying out potentially major research and development (R&D) activities. Those activities, it was thought, would be pursued within the aerospace industry under Government contract rather than "in-house" with Federal laboratories. They thus concluded that the creation of an essentially new Federal structure for space, but one built around the **NACA core of technical capability and research institutions, was the appropriate route to go.**

In the National Aeronautics and Space (NAS) Act of 1958, the primacy of civilian objectives in space was stated: "it is the policy of the United States that activities in space should be devoted to peaceful purposes for the benefit of all mankind;" and the responsibility for those activities was given to a civilian agency: "Such activities shall "be the responsibility of and shall be directed by a civilian agency exercising control over aeronautical and space activities sponsored by the United States."

One area of controversy in the development of the 1958 NAS Act was whether the new space agency should be responsible for all space R&D, including that ultimately to be used by the military for defense applications. The decision was to make explicit from the start the total separation of these two major categories of space activities, with the National Aeronautics and Space Administration (NASA) having no direct involvement in military work. Thus, the NAS Act also declared that DOD should have responsibility for "activities peculiar to or primarily associated with the development of weapons systems, military operations, or the defense of the United States (including the research and development necessary to make effective provisions for the defense of the United States)."

The formal separation of the civilian and military space activities into different institutional frameworks meant transferring to the new civilian space agency functions related to its mission but under military control and, particularly after NASA had been assigned the lunar landing mission, developing new capabilities required to carry out an active space R&D effort. Within DOD there was a desire to develop a space R&D and a space operations structure, and to determine the division of responsibility at the Secretary of Defense level between the various military services. Both the NASA buildup and the development of the initial military structure for space were accomplished by the early 1960's.

Within the first 2 years of its existence, NASA had transferred to it a number of facilities, programs, and personnel that had formerly been operating under military auspices. These included, from the Army, the Von Braun rocket development team at Huntsville, Ala. (which became the core of the Marshall Space Flight Center), and the Jet Propulsion Laboratory at the California Institute of Technology. NASA was authorized to develop several new field centers related to its mission, including the Goddard Space Flight Center for science and applications programs and the Manned Spacecraft Center (later the Johnson Space Center) for manned programs, and to develop a civilian launch facility at Cape Canaveral, Fla. (later the Kennedy Space Center).[1] These were added to the three former NACA centers: Langley, Lewis, and Ames; in addition smaller NACA facilities at Wallops Island, Va., and Edwards Air Force Base, Calif., came under NASA control. By 1962, NASA had in place an impressive institutional capability, one fully mobilized for meeting a broad set of national objectives in space.

This Government institutional base for civilian space programs was reinforced by the development of an elaborate external network of organizations—industries, universities, and nonprofits—involved in carrying out the civilian space program under NASA contracts or grants. In addition, as space activities matured, other Government agencies, including the Departments of Agriculture; Commerce; Energy; Health, Education, and Welfare; and Interior also became involved in space-related activities. At the peak of the Apollo program in fiscal year 1965, fully 94 percent of NASA's budget obligations went to external grants and contracts, and NASA's prime contractors in turn created a wide base of more specialized subcontractors. Of direct NASA procurements in that year, 79 percent went to business firms, 8 percent to educational institutions, 12 percent to other Government agencies, and 1 percent to nonprofit organizations. This pattern has remained consistent over the years; in fiscal 1978, the same percentage (94 percent) of NASA's budget went to extramural procurement, and the distribution among performers was rather similiar—business (81 percent); educational institutions (12 percent); nonprofits (1 percent); and other Government agencies (6 percent).

As the development of Government space activities during the 1960's and 1970's continued, the separation between the civilian and military (including intelligence) communities became quite pronounced. The Government developed and maintained separate and distinct institutional structures for both functions, not only in terms of line agencies within the executive branch, but also in terms of policy review, budget development and review, and congressional oversight. The elements of the Government space program coordinated their work but in a limited way compared to the separate efforts developed by each element of the Government space effort.

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[1] **There was already a military launch facility at the Cape.**

The **NASA structure created under the direction of its first two administrators, Keith Glennan and James Webb, has remained basically unchanged during the past two decades. NASA headquarters in Washington is responsible for policy development and overall management and technical direction of the various components of the civilian space research program. Technical management of those specific projects is assigned to one of the various** NASA field centers. NASA has adopted the "Air Force model" of agency-contractor relationships, in which most R&D work is performed outside the Government by the aerospace industry. The Government role is that of program and project initiator, technical monitor of contractor performance, and user of the results of the R&D efforts.

The set of field centers under NASA authority today is the same as it was during the early 1960's.[2] Because NASA is responsible for civilian space activities aimed at a number of different purposes, including science, applications, and development of technological capability, and because the responsibility for each of those missions is lodged in a different field center, one of NASA headquarters' major responsibilities is allocating priorities and resources across the NASA institutional complex. The vitality of various field centers is closely related to the priority assigned to particular types of space activities under that center's control, and thus there is strong institutional motivation to compete for particular emphases within the overall NASA program.

Congress dealt with the need to establish a firm policy foundation for space by creating two temporary select committees in early 1958. Later that year it established two new standing committees to deal with civilian space matters. In the Senate this responsibility was given to the Committee on Aeronautical and Space Sciences; in the House, to the Committee on Science and Astronautics. Both of these committees derived their visibility and status within Congress from the importance of program oversight and their authorization authority over those programs. As long as the civilian space program was a matter of high national priority with major budgetary support there was a corresponding degree of status in being involved with these two congressional committees. However, as the resources allocated to civilian space activity declined after Apollo, Congress viewed space activities as just one among various science and technology programs of Government, and during the 1970's committee jurisdictions and names were modified to reflect this reality. Now **the** programs **of** NASA **and the National Oceanographic and Atmospheric Administration are** reviewed in the Senate by the Subcommittee on Science, Technology, and Space of the Committee on Commerce, Science, and Transportation; there is no separate Senate Space Committee. In the House, the Committee on Science and Astronautics in 1974 was renamed the Committee on Science and Technology and its jurisdiction was broadened to cover most civilian science and technology activities, rather than being focused primarily on NASA efforts.

This institutional base offers the potential for rapid mobilization if the Nation decided to accelerate the pace of its civilian space effort; the consequences of allowing the NASA and contractor institutional bases to shrink are unclear. It may be a sound *national* investment to maintain a strong institutional capability within the Government for civilian space development, even though that capability is not always being fully utilized. On the other hand, as this report has argued throughout, it may also be appropriate, as U.S. activities in space mature, to shift more of the responsibility for program and project planning and development for space applications and transportation to the private sector, with a parallel diminution of Government's institutional involvement.

In 1977-78, a National Security Council Policy Review Committee reviewed the structure of the national space program. The report validated the fundamental principle of separating civilian and military space activities. It concluded that "our current direction set forth in the Space Act in 1958 is well-founded" and that "the United States will maintain current responsibility and management among the various space programs. "3

Policy and Program Coordination

The decision to separate civilian and military space activities led naturally to the requirement for policy and program coordination between the programs. The type of policy coordination needed and mechanisms for coordination have been, and continue to be, controversial issues (see ch. 6). The nature of coordination at the program level has been less problematic and working-level cooperation between civilian and military space efforts has been the rule. However, occasional disputes have arisen over, for example, proposed civilian uses of technology developed for national security purposes.

During the 1958 debate on space policy, a major congressional concern was the relationship between military and civilian objectives in space and some broader set of national interests. Senate Majority

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[2] **Except for the brief period during which NASA also had an Electronics Research Center in Cambridge, Mass.**

[3] **The only public announcement of the results of this review was in the form of a June** *20,* **1978, press release from the White House,**

Leader Lyndon Johnson, in particular, was convinced that space policy ought to be the subject of Presidential attention; the Eisenhower administration was far less convinced that space policy deserved such high priority. Johnson wanted to coordinate policy at a high level by creating an Executive Office group modeled on the National Security Council but dedicated specifically to aeronautical and space activities. The Eisenhower adminstration reluctantly accepted Johnson's notion as a price of getting the space legislation through Congress, and a National Aeronautics and Space Council was established by the NAS Act. The Space Council was to be a high-level advisory body, chaired by the President and consiting of the heads of other agencies concerned with space activities and several nongovernmental members.[4] It was to assist and advise the President in developing a comprehensive program of aeronautical and space activities, in assigning specific space missions to various agencies, and i n resolving differences among agencies over space policy and program.

Although the Eisenhower adminstration agreed to the inclusion of the Space Council in the legislation setting up the national space effort, it never used the Council. Rather, space policy under Eisenhower was developed through the channels of the National Security Council and Bureau of the Budget. Eisenhower believed that civilian and military functions in space development were "separate responsibilities requiring no coordinating body. " Thus, in 1960 he asked Congress to abolish the Space Council.

This proposal was sidetracked by Lyndon Johnson. When Kennedy won the 1960 election, with Johnson as his Vice President, the new President was convinced to keep the Space Council but to change the legislation so it would be chaired by the Vice President. During the Kennedy administration, the Space Council hired its first staff members and played an active role in developing the national policies that led to the Apollo project and to the administration's position on communications satellites. In the rest of the 1960's, under the Johnson and Nixon administration, the Space Council continued to exist, but stood at the margins of most space policy debates. it developed a relatively large (for the Executive Office) staff under the leadership of Vice Presidents Hubert Humphrey and Spiro Agnew. **However, as the priority assigned to the civilian space program continued to decrease** in the President's agenda and as the separate space activities of the Government became governed increasingly from within the separate agencies, the Space Council became rather a moribund institution, and in 1973 President Nixon proposed its dissolution. Congress raised no objection and the Space Council went out of existence.

Without a central policy coordinating structure during the 1970's, stresses among various Government space activities developed. Several of these were the results of disagreements between **NASA and** DOD over the appropriate national security constraints to be applied to civilian space efforts, particularly for Earth observations. NASA-DOD relationships with respect to the space shuttle program have been another area of controversy. It was these stresses that were the primary cause of the Carter administration review of national space policy that began in 1977.

A major result of that review was the reestablishment of a Presidential-level policy review process for space. The process existed in the form of a Policy Review Committee (Space), operating under National Security Council auspices but chaired by the Director of the Office of Science and Technology Policy. This committee provided a forum for all involved Federal agencies (including Departments such as Interior and Agriculture) to air their views on space policy, to advise the President on proposed changes in national space policy, to resolve disputes among agencies, and to provide for rapid referral of space policy issues to the President for decision when required. Unlike the Space Council, the Policy Review Committee (Space) did not have a standing professional staff structure. Rather, it served as recognition of the need to formalize the channels of interaction among the various components of Government space activity rather than have policy and program disputes settled through the budgetary review process or other means of interagency coordination.

The structures for coordination among military and civilian space efforts at the program level have had a rather different history than those for policy-level coordination. The 1958 NAS Act created an institution for coordination at this level, the Civilian Military Liaison Committee (CMLC), but that statutory committee, like the Space Council, was a congressionally imposed structure and was seldom used. Rather, NASA and DOD set up a number of working-level groups on issues of interest to both agencies as the early years of the space program passed. CMLC was eventually abolished and replaced by a nonstatutory Aeronautics and Astronautics Coordinating Board (AACB), which formalized the contacts between NASA and DOD at the working level. AACB was established by NASA-DOD agreement in 1960 and was given responsibility for coordinating NASA and DOD activities so as to "avoid undesirable duplication . . . achieve efficient utilization of available resources" and undertake" the coordination of activities in areas of

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[4] These nongovernmental members were never appointed and the positions were eliminated when the Space council was reorganized in 1961.

common interest. The early years of AACB were quite productive in terms of data exchanges and creating an awareness of what the other agency's plans were; **AACB continues to exist today as the primary mechanism for addressing major program** issues of interest to DOD and NASA in space. However, as the separate NASA and defense programs became more institutionalized in the 1960's and 1970's there has been a tendency for coordination between the programs to be defensive in character, i.e., aimed at protecting each agency's own programs and "turf."

From Research to Operation

In the 1958 debate over space activities the notion of operating civilian space systems did not receive much attention. The NAS Act gave **NASA the responsibility for most aeronautical and space activities but defined those activities as: 1) research into problems of flight within and outside the Earth's atmosphere; 2) the development, the construction, testing and operation for research purposes of aeronautical and space vehicles; and 3) such other activities as may be required for the exploration of space. This language seemed to limit** NASA to R&D activities, and that was the general understanding of the agency's mission at the time.

By providing launch services to a variety of customers, including other Government agencies, the Communications Satellite Corporation (COMSAT) and other private sector firms, and other countries, NASA has gone beyond R&D to a clearly operational role in one area. Restriction to R&D has had little impact on NASA's efforts in space science and exploration or technology development, but it has had a definite impact for space applications.

Limiting NASA to the R&D part of the job of bringing space applications into being means that other users of space technology are necessarily involved in the total applications effort. **NASA has developed an orientation toward "technology push" efforts rather than a tradition of close coupling with potential** users of space technology who would exercise "demand pull" on the development of space applications. While NASA has almost from its start included "technology transfer" functions in its organization, many observers think that NASA has so far done an inadequate job of marketing its technological capabilities to potential users of space application systems.

While an emphasis on developing and demonstrating new technical capabilities is often necessary to convince potential users of their value, especially in situations where no preexisting user community exists, most observers believe that **NASA, particularly in its early years, put** more stress on pushing the technological frontier in space applications than on developing technology either in response to user demand or in anticipation of the kinds of demands likely to arise as new capabilities became known. In addition, NASA has developed a history of emphasizing the development of constantly more sophisticated technology in its application programs rather than concentrating on bringing an adequate application system into early operation. This is at least in some measure a reflection of the institutional reality that, once NASA completes R&D for an applications program, it must transfer that program to some user outside of the agency. There is an organizational tendency to attempt to hold onto programs, even if that means prolonging the R&D phase beyond the socially optimum points Since the early 1970's, **NASA has placed a high priority on developing closer relationships with potential users of space technology, particularly** in remote sensing and advanced satellite communications.

The first test of NASA's bias toward continuing R&D in applications was in weather satellites. in the early 1960's NASA's initial meteorological satellite program, which had been transferred from DOD, was called TIROS. As the agency in charge of space R&D, **NASA regarded TIROS as only the first** step in weather satellite development and wanted to go immediately to the creation of an advanced meteorological satellite called NIMBUS. The Weather Bureau within the Department of Commerce, a potential user agency, had another point of view. TIROS would markedly improve its services, and the Weather Bureau wanted NASA to focus on it rather than initiate a new weather satellite program. However, it took several years and substantial bureaucratic conflict before NASA was willing to shift its emphasis away from the advanced NIMBUS development program back to completing TIROS and bringing it to an operational state.[6] Eventually, NASA worked out an effective agreement with the Weather Bureau both to support on-going meteorological satellite activities and to continue R&D on advanced sensors relevant to meteorological applications.

The complex history of the use of satellites for remote sensing of land and ocean areas demonstrates the institutional problems stemming from, among other sources, NASA's focus on R&D and its lack of close links with potential users of operational space systems. The debate over the appropriate develop-

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[5] There may be technical and managerial as well as institutional reasons why the development of a space application may take longer than originally hoped for. Some also suggest that there have been instances of premature shifts from R&D to operational status in space applications.

[6] For a detailed account of the NASA/Weather Bureau dispute, see Richard Chapman, *TIROS-NIMBUS: Administrative, Political, and Technological Problems of Developing Weather Satellites* (Syracuse, N. Y,: Interuniversity Case Program, Inc., 1972).

ment pace and management structure for the Landsat system has extended over a decade.

A major issue as arrangements for operational land remote sensing have been debated is whether NASA's charter ought to be revised to extend its authority to the operation of space applications sytems. The Presidential directive of November 1979 ended this debate with the decision to keep NASA as an R&D agency in remote sensing and to assign civilian Earth observation operations within the Government to NOAA, even though there were other claimants to a share of the operational remote-sensing role such as the Department of the Interior and the Department of Agriculture. Throughout the Landsat program, NASA has emphasized the experimental nature of the early remote-sensing satelites. While it has worked with potential users to make them aware of possible applications of Landsat data to their programs, it has also proposed more advanced sensors for orbital evaluation in later Landsat satellites, but it has not given priority attention to developing the ground segment, including associated data management and information processing and dissemination systems, required for early deployment of a first generation operational remote-sensing system.

Public-Private Sector Relations

NASA's relationships as an R&D agency for space with other potential users of space applications are relatively underdeveloped; this is particularly the case when those users are not other Government agencies, but rather private sector, profit-oriented firms. The appropriate division of responsibility between public and private organizations for research and development oriented toward commercial applications for space technology has been problematic since the start of the space age.[7]

This issue initially surfaced in communications satellite research. The Eisenhower adminsitration recognized that communication via satellite was an area of potential major economic payoff and decided, in keeping with its general pro-business orientation, that communication satellite research should be left to those interested in making a profit in it. Others, however, feared that allowing only private entitites to develop the technology of space communications meant in effect giving a virtual monopoly in that area to the corporation with the most resources available to invest in communications satellite research, American Telephone & Telegraph (AT&T). From the perspective of those interested in preventing monopoly power in new areas of human activity, such a development was not desirable. The situation was further clouded by the recognition that, even if AT&T or another private entity developed a communications satellite using its own funds, it would have to depend on launchers developed with public money to place that satellite into orbit. Thus the Kennedy administration reversed the Eisenhower policy of leaving communications satellite research to the private sector; Kennedy authorized NASA to conduct a vigorous program of research in the communications satellite area.

There were some in 1961 and 1962, as space communications approached reality, who thought that the Government should not only be involved in communications satellite R&D and make the results of that research available to a variety of potential private sector firms for commercialization, but also that the Government itself should take advantage of that research and undertake the operational satellite communications role, returning the eventual profits to the Treasury. The advocates of this position were not able to gather majority support in the 1962 debate over communications satellite policy. With the creation of a new institution, COMSAT, which had some aspects of public control but was fundamentally a new private enterprise, the notion that the Government should go into the communications satellite business itself disappeared.[8]

The precedent established during the communications satellite debate was that developing new applications of space technology with commercial potential and nurturing them to operational status is a mixed private sector-public sector responsibility, with the appropriate division of roles to be determined on an ad hoc basis for each area of applications; the goal, however, is eventual private sector operation of civilian space application systems. In each area in which a space application has reached or approached maturity, such as point-to-point communications and some applications of satellite remote sensing, business structures have emerged that operate as commercial enterprises related to that application. The Government has continued to fund research in other areas of space applications with potential commercial utility, including space transportation, materials processing, and other aspects of remote sensing, with the hope of discovering whether there are indeed profitable opportunities for private sector involvement in those areas, and demonstrating to potential operators what those opportunities are. It maybe that continued Government

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[7] This problem is not limited to the space sector. The issue of Federal policies affecting private sector innovation, including direct support of civilian R&D, has been a subject of much recent discussion within both the executive branch and Congress.

[8] For a full discussion, see Jonathan F. Galloway, *The Politics and Technology of Satellite Communications* (Lexington, Mass.: D.C. Heath & Co., 1972).

willingness to push the applications of space technology and to bear the costs and risks of the research, development, and demonstration phases of commercializing those applications is the only way for some of them to become reality, at least in the short to midterm.

Advanced communications was one area of policy and institutional controversy during the Nixon and Ford administrations. NASA was ordered in 1973 to end its communications R&D efforts, on the grounds that the space communications business was far enough advanced so that it should be totally a private sector responsibility. The consequence of this decision was that the U.S. private sector concentrated on only those aspects of space communications which had the promise of early commercial payoff; other governments, most notably France and Japan, have provided R&D support for advanced space communications development, leading to increasing international competition with U.S. firms for sales of advanced communications satellites. This situation led the Carter administration in 1978 to decide that the potential economic and social benefits of communications satellites were not being adequately tended to by private sector R&D. The Carter administration reestablished a NASA research effort in advanced space communications and Information Administration of the Department of Commerce with assisting in market aggregation and possible development of domestic and international public satellite communication services.

From “Preeminence” to “Leadership”

President Kennedy in 1961 committed the United States to a policy of “preeminence” in all areas of space activity. The notion that the United States should maintain a position of “leadership” in space activity has been repeated by each Chief Executive since Kennedy,

As other countries in Europe, Asia, and South America develop independent space capabilities and as the Soviet Union continues an extremely active space effort, how the United States will continue policies of “leadership” and “preeminence” is unclear (see chs. 3, 9, and 10). One possibility is for the United States to compete across the board with other nations in all areas of space activity, from the development of large, permanent manned structures in orbit, through various types of space applications, to exploration of the cosmos. Another option is to focus U.S. space priorities in areas of high national payoff (which would include international leadership in those areas). Another option is to view application activities in space as competitors with Earth-bound enterprises, and to undertake them only when they are the most efficient means of meeting broader national objectives.

The initial result of the commitment to across-the-board preeminence was to create in NASA an agency with the structure, institutional relationships, and organizational culture needed to carry out a high-priority, nationally mobilized effort to developing a large-scale technology. NASA, at least in formal terms, remains today an organization designed for such purposes, but the terms of a national commitment to Leadership in space activities are much less clear than they were during the peak of the Apollo program in the mid-1**960’s. As space activities have matured, and as they promise to grow and** become even more routine over the coming decade, a major institutional issue is whether a single central space agency with the desire and structure for carrying out an integrated, high-priority national space effort in the civilian sector is an anomaly.

The International Context: Cooperation and Competition

During the 1960’s, NASA developed international cooperative programs that were clearly secondary in priority to using space technology as a demonstration of national technical resources. Almost all of NASA’s international activities were scientific in character and were carried out under policy guidelines that kept them limited in scope, including the restrictions that cooperation had to be based on mutual scientific benefit and that there would be no exchange of funds between the United States and its partners in international space activities. This limited concept of international cooperation was broadened during the 1970’s to the applications area, as a number of nations become interested in the Landsat program, building their own ground stations or otherwise receiving Landsat data, and for the first time paying NASA a fee for access to the remote-sensing satellites. Other application efforts also had international dimensions; for example, the Application Technology Satellite and Communications Technology Satellite programs demonstrated some of the uses of communications satellites for education and health care in both developing and industrialized countries (see ch. 7).

Also during the 1970’s, there was limited use of international cooperation in space technology to serve what were explicitly foreign policy goals. The leading

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[9] A major exception was the set of international agreements required to establish a global tracking network,

[10] For the foundations of U.S. policy toward international cooperation, see Arnold Frutkin, *International Space Cooperation* (Englewood Cliffs, N. J.: Prentice Hall, 1965); for criticism, see Don Kash, *The Politics of Space Cooperation* (West Lafayette, Ind.: Purdue University Studies, 1967),

example was U.S.-U.S.S.R. cooperation in the Apollo-Soyuz test project. Increasingly, the potential of space as a tool of our foreign assistance program and as a means of demonstrating our concern for the developing countries has led to assistance programs in a variety of third- and fourth-world countries that use Landsat data.

Cooperation with our major industrial partners and potential competitors in space technology development began during the same time period. The European Space Agency assumed the responsibility for developing the Spacelab, which is to be flown on the shuttle as a base for orbital scientific experiments requiring the presence of human experimenters. The U.S. stance toward cooperative programs that would develop commercially useful space technology is however, somewhat ambivalent, because of possible economic returns from these activities and because of the desire of the United States either to maintain or establish a competitive advantage.

‘As other major nations develop advanced space technology, the mixture between international **competition and international collaboration** in space should be a dynamic one. Competition between U.S. and European launch vehicles for payloads in the 1980’s is just one example. A number of issues being debated in international forums could affect U.S. civilian space activities in the coming decades. Examples are the actions of the World Adminsitrative Radio Conferences in allocating frequencies (and potentially slots in geosynchronous orbit) and the debate in the United Nations **on a Moon treaty.** The United Nations has also scheduled a Conference on Space Applications for 1982.

The Soviet Union, West Germany, France, Japan, Brazil—and indeed a number of other countries—are allocating significant resources to space R&D. In coming years, the U.S. civilian space program will function in an international context quite different than has been the case. The institutional implications of this changed context—for example, how to relate space activities to foreign policy objectives and how to carry out the diplomacy required to support our space objectives— require examination.

Appendix B

USE OF LANDSAT DATA BY THE BUREAU OF LAND MANAGEMENT OF THE DEPARTMENT OF THE INTERIOR

Introduction

This case study was prepared by the Bureau of Land Management (BLM) of the Department of the Interior to illustrate its use of Landsat data. It shows that Landsat data have become an integral part of BLM's strategy for managing the land and resources under its care.

BLM utilizes Landsat data in numerous programs. These programs use both photographs and digital tape products. Interpreted Landsat data are used to assist in mapping basic vegetation, soils, geology, and energy and mineral resources. The processes of interpretation range from very basic and efficient visual interpretations of Landsat photographs to highly technical and complex digital image processing of digital tapes. Table B-1 lists some examples of past and current programs conducted in BLM that have made use of Landsat data. BLM views Landsat and any other remote-sensing technologies as basic tools. The products of these tools are integrated and are then used within the frameworks of various programs to improve their quality and efficiency as well as to reduce program costs. Thus, Landsat data aid BLM in inventory and planning primarily by streamlining and structuring these activities.

Table 6.1 .—Examples of Past and Current Programs Utilizing Landsat Data

	f_andsat-aided program	Location	Size (acres in millions)	Status		Task/purpose
				Complete	Current	
1.	Denali Project	Alaska	3.5	x		Test and evaluate Landsat aided resource mapping in northern spruce tundra biome.
2.	AVRI Project	Arizona	2.1	x		Test and evaluate Landsat.aided resource mapping in the Southwest desert community.
3.	IVRI Project	Idaho	3.7	x		Test and evaluate Landsat-aided resource mapping in sagebrush grassland community.
4.	California Desert Plan	California	25	x		Fulfill requirements of Federal Land Policy and Management Act.
5.	Northwest Tier Pipeline	Oregon	3.0	X		Provide information for environmental statement.
6.	Taos Project	New Mexico	5.8		x	Provide information for Planning System.
7.	Havasu Project	Arizona	1.0		x	Provide basic soils prestratification.
8.	Jarbidge Project	Idaho	1.3		x	Provide information for Planning System.
9.	Mining Disturbance	Missouri	3.0		x	Detect and map mining trespass.
10.	Fuels Mapping	Alaska	5.0		x	Map fuels loading in areas in high wildfire potential.
11.	Phoenix Project	Arizona	6.3		x	Provide information for Planning System.
12.	Coeur d'Alene	Idaho	1.0		X	Update existing forest inventory.

SOURCE: Office of Technology Assessment.

Two Activities of Importance to BLM

For the purpose of this report, two activities in BLM have been selected for detailed analysis. Both are encountered daily in BLM State and district offices and both share the common thread of requiring inventory information for application to resource management. The first application is known as the planning system and requires a more generalized level of inventory data than the second program. This second program, the soil vegetation inventory method (SVIM), is a field-intensive effort that requires a detailed inventory data set. These data are used for such tasks as allocating grazing lands. For the details of the programs, the reader is referred to the manuals that are listed in the bibliography at the end of this report.

The Planning System

The BLM planning system provides a systematic approach to gathering, analyzing, and integrating multiple resource data into an overall management plan. The system permits informed and objective multiple-use decisions through identifying and reconciling conflicting land and resource uses. It is an internal management tool that helps blend diverse authorities and land use opportunities. It is also a managerial system through which the BLM Director, State directors, and district managers develop and manage the various BLM program activities. Each of these activities has a primary mission or purpose for which objectives and standards are defined. This system provides for a multiple resource program consisting of: lands, minerals, recreation, wildlife, watershed, forestry, and range. The system consists of three basic steps. These–unit resource analysis (URA), managment framework plan (MFP), activity plan–are briefly described below.

Components of the Planning System

- ***Unit resource analysis*** (URA).—URA provides a comprehensive analysis of inventory data, resource problems, conditions, users, production, quality, capabilities, and management potential for use in preparing a management framework plan. **In other words, URA provides resource** information pertinent to decisions about land use resources management in a unit of land. It also provides continuity in retaining and maintaining resource data. URA supports the multiple-use concept and is prepared by individual resource specialists.
- *Management framework plan (MFP).* —M FP reconciles conflicts in land and resource use. Planning decisions are made for specific areas so that the unique characteristics of each area are fully considered. MFP indicates what is to be done with each resource within each unit.
- *Activity* plan.–The activity plan is prepared for each individual resource unit to define the manner in which the resultant activities shall achieve the objective and constraints of the MFP. The activity plan is specific to the users and special interests involved. An allotment management plan is an example of an activity plan.

Since its development and adoption by the entire BLM in 1969, the planning system has been a major factor in BLM program activities. All BLM offices, including the Outer Continental Shelf Program, employ the technique. Its primary strength is that it has systematized the planning process, and enhanced the quality of BLM management. However, it is labor intensive. During the last 5 years, approximately $60 million have been budgeted for planning system applications, with an estimated workforce of 450 positions.

A variety of products are required in the planning system. Figure B-1 is an example of the basic unit resource analysis map depicting current vegetation. Figure B-2 is an example of a wildlife habitat overlay showing areas of Desert Tortoise habitat. Table B-2 is an example of tabular data utilized within the process. Although BLM is the primary user of the information, numerous other individuals, organizations, and private concerns have access to the data, e.g., local ranchers, environmental societies, and Federal and State Government agencies.

Soil Vegetation Inventory Method

SVIM is the BLM method for conducting basic soil and vegetation inventories. SVIM supports the planning system as well as other activities such as environmental statements. The process provides a uniform and systematic method of detailed inventory. It does not inventory all renewable resources. However, it does provide a framework for inventories of the numbers and kinds of wildlife species, and also gathers basic data for use in other resource inventories.

SVIM evolved from a number of requirements, but the primary catalyst was the need to acquire high-quality resource data for use in developing environmental statements concerning grazing. Since its inception in 1978, it has been applied in a variety of forms throughout BLM. The major strengths of this procedure are: 1) the high-quality data that are available as a result of data collection in the field; 2) ability to integrate soils and vegetation information in the mapping process; and 3) the vast wealth of data that are available for use once the inventory is completed. The

Figure B-f.—Vegetation and Soil Associations

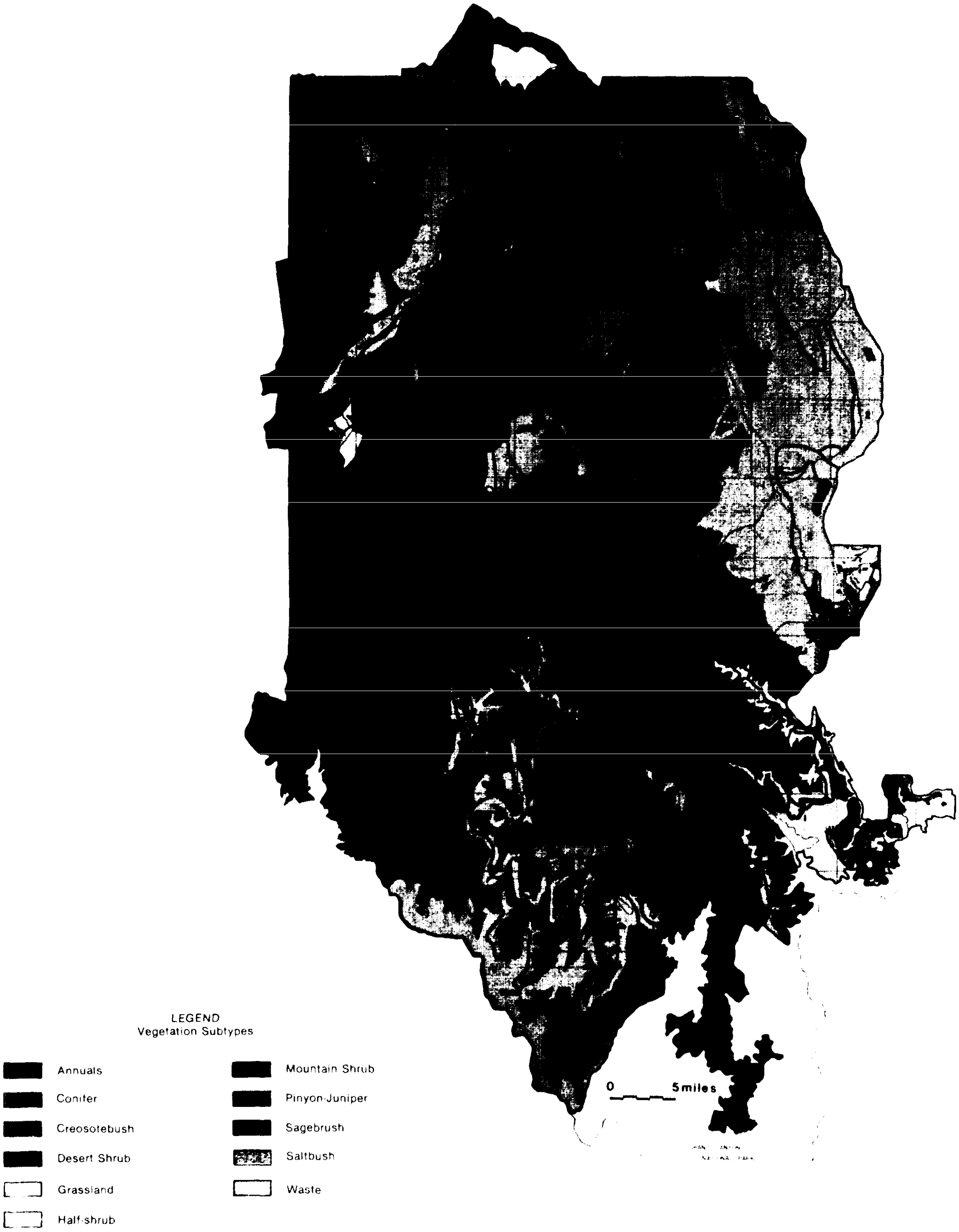


Figure B.2.— Desert Tortoise Habitat

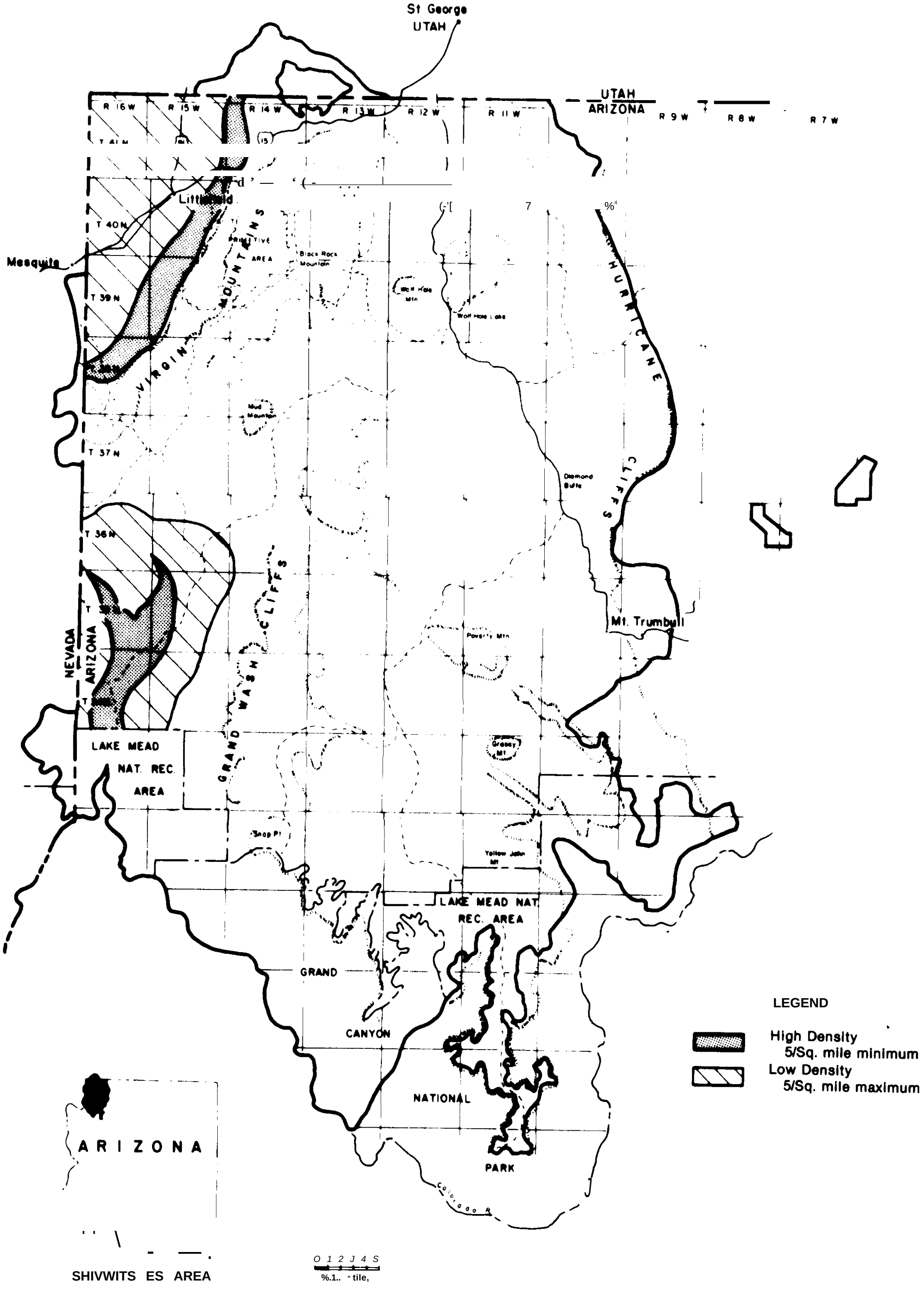


Table B-2.—Tabular Data Used in the Planning Process

Allotment	Vegetation subtype	Current key species composition		Proposed action alternative 3 future key species composition		Full stocking		Stocking by condition		No action		Elimination	
		Grass	Shrub	Grass	Shrub	Grass	Shrub	Grass	Shrub	Grass	Shrub	Grass	Shrub
Wolfhole Mountain	Blackbrush	I	14	T	14	T	14	T	20	T	14	T	14
	(Treatment)	—	—	(40)	(20)	(40)	(20)	(40)	(20)	—	—	—	—
	Desert shrub	8	6	8	6	8	6	8	6	8	6	8	6
	Sagebrush	4	11	4	11	4	11	4	11	4	11	4	11
	(Treatment)	(4)	(11)	(35)	(25)	(35)	(25)	(35)	(25)	—	—	—	—
	Pinyon-juniper	2	23	2	23	2	23	2	23	2	23	2	23
	(Treatment)	(2)	(23)	(40)	(20)	(40)	(20)	(40)	(20)	—	—	—	—
Wolf hole Lake	Grassland	35	12	40	12	35	12	47	12	35	12	38	12
	Sagebrush	35	0	45	0	35	0	47	0	35	0	42	0
	(Treatment)	(35)	(0)	(50)	(0)	(35)	(25)	(35)	(25)	—	—	—	—
	Annuals	5	T	10	5	5	T	10	5	5	T	9	5
Wolf hole Canyon	Desert shrub	10	18	15	23	15	23	10	24	10	18	14	21
	Creosotebush	9	22	9	22	9	22	9	29	9	22	9	20
	Annual grass	20	T	25	T	25	T	25	T	20	T	23	T
	Sagebrush	20	5	25	10	25	10	25	10	20	5	23	T
	(Treatment)	(20)	(5)	(40)	(20)	(40)	(10)	(40)	(10)	—	—	—	—
	Grassland	44	11	60	11	60	11	59	11	44	11	56	11
	Pinyon-juniper	16	T	16	T	16	T	16	T	16	T	16	T
Mine Valley	Creosotebush	T	5	T	5	T	5	T	5	T	5	T	5
	Desert shrub	10	20	15	25	10	20	15	27	10	20	14	23
	Blackbrush	T	15	T	15	T	15	T	15	T	T	T	T
	Grassland	55	10	70	10	55	10	74	10	55	10	64	10
	Sagebrush	5	10	5	10	5	10	5	10	5	10	5	10
	Pinyon-juniper	T	5	T	5	T	5	T	5	T	5	T	5
Cedar Pockets	Pinyon-juniper	T	5	T	5	T	5	T	5	T	5	T	5
	Desert shrub	10	20	15	25	10	20	13	27	10	20	12	23
	Joshua tree	10	15	15	25	10	15	10	20	10	15	13	23
	Grassland	55	10	70	10	55	10	74	10	55	10	64	9
Shelly	Grassland	42	16	52	21	42	16	57	16	42	16	49	20
Snyder	Grassland	53	3	68	3	53	3	71	3	53	3	64	3
	Sagebrush	31	T	41	T	31	T	41	T	31	T	39	T
Unallotted	Desert shrub	5	10	5	10	Same as current species composition							

SOURCE: Bureau of Land Management

process also has a few weak points. For example, the detail that is listed as a strength is also a weakness because of the labor-intensive nature of detailed field work. Similarly, without a means of automatically handling the data, the voluminous amount of data available are not readily usable. Another related weakness is the cost of these inventories. Recently programs have been developed on the mainframe computer system at Denver Service Center to store and manipulate the tabular data collected in SVIM. In addition, a linear optimization model has been developed to allocate vegetation production among the competing uses. To date, this tabular data has not been tied to a digitized mapping process.

In the 3 years since the SVIM inventories were established, an estimated $14 million have been spent on them. They have covered about 32 million acres and have required 7,200 work-months. A skill mix of vegetation, soil, forestry, wildlife, and range conservation specialists, wildlife specialists, etc. have been involved in these inventories.

Transition to the Use of Landsat Data

BLM has followed an organized approach in the test, evaluation, and implementation of Landsat data. A complete description of that approach can be found in several reports (see bibliography). In 1977, *BLM,* National Aeronautics and Space Administration (NASA), and the **U.S.** Geological Survey EROS Program agreed on a phased program to implement this technology in BLM. The program was designed to provide BLM an opportunity to test the technology in an operational manner, to evaluate the results of the tests, and finally to implement those aspects of the technology most suited to assist BLM data collection and resource management needs. During this transfer of remote-sensing technology to BLM, BLM assimilated the procedures and equipment into a small core staff housed within an existing research and development (R&D) organization at the Denver Service Center. From this core staff of three persons, the present Branch of Remote Sensing (BRS) grew. A continuing process of reporting and reviewing the status of the program was followed that resulted in many changes to the program. These changes were implemented on a test site basis. Since the project was structured to test the technology in three diverse areas, changes in program orientation were made at the onset of activities in each subsequent test site. This procedure provided BLM: 1) time to plan carefully and implement the changes, 2) ability to build upon each test site in a systematic fashion, and 3) prevention of unnecessary and costly changes within each phase of the program. At this time, the program has been incorporated in the operations of BLM; and Landsat-assisted programs are currently being conducted in several areas.

In addition to the program just described, a number of other factors have caused the BLM to use Landsat data. For example, the congressionally mandated California Desert Plan (CDP) utilized Landsat imagery because of tight schedules and funding. in this study Landsat data were used to view the unit at a broad scale from which areas for intensive study were chosen. These areas were then sampled with finer scale methods appropriate to the resource requirement, e.g., aerial photography. Vegetation, soil geology, energy, and mineral resources were included **in the effort. Without Landsat, it is questionable that CDP** would have been accomplished within the time and cost constraints. **In addition, there is the natural process whereby technology is used by personnel in the field because of the acute** needs for data that exist at the working level. That is, if a technology can be utilized to acquire information needed at the field level then it is often used without prior knowledge of management. **There is no doubt that the methodology would have gained use and acceptance in** BLM, but the major program described in the preceding paragraph caused a more organized and Bureau-wide adoption.

Transition to Space Data

It is of paramount importance that the reader keep in mind the closing words of the first paragraph of this report: "Landsat data aid the BLM in inventory and planning by streamlining and structuring these activities." Landsat data are used to improve inventory quality, to enhance data retention and renewal, and to reduce inventory costs. The use of Landsat data has not led to replacing programs. Thus, Landsat is primarily a new tool that is available to the resource specialist to enhance his product. BLM is currently developing guidelines to the field offices for the use of this new tool and is becoming increasingly dependent on it to effect required operating economics.

USER ACCEPTANCE

Whether field people will accept and utilize new approaches and whether management will believe results obtained through these new concepts, are major factors in the transition, In any organization, the "field type" is notoriously concerned that any change may adversely affect his ability to do the field work that is so necessary for good management practices. Similarly, management personnel are reluctant to change something that heretofore has worked well. These are valid concerns that were recognized in the project planning stages of this program. In order to combat these fears an extensive educational program was incorporated as an integral part of the study. Since the beginning of the program, training courses in remote sensing have been a mainstay of each phase of the project. The sessions have covered basic photo interpretation procedures as well as advanced digital image processing. In addition, they have addressed a variety of subjects—vegetation, geology, soils, etc. To date, over 750 BLM resource specialists have received training through these programs. This training is continuing on an annual basis, and in the near future, special sessions specifically oriented to managers are planned.

Program Continuity

In the last **5** years **BLM has made a substantial commitment to the use of Landsat data. This commitment represents a major investment of labor and equipment. Thus, the continuation and improvement of the Landsat system is of vital interest to BLM. At this time, it is understood that Landsat D' is the last satellite authorized** for the program. The prospect of terminating the Landsat program will greatly affect the future decisions of BLM toward continued use of Landsat data. Reluctance to adopt a full-scale program can be expected. Managers must have a guarantee that data will continue to be available before they can be asked to embrace the technology. BLM is willing to consider other alternatives, such as using data from the proposed Japanese and European satellites. However, these satellites are not in orbit and can only be considered as potential alternatives. In addition, there doesn't appear to be any assurance that the desired private sector takeover of Landsat is likely. Thus, to a user organization like BLM, the picture is confusing and bleak. In the face of continued increasing costs for all services, BLM shall seek to make its limited inventory dollars stretch even further. Present policies do not seem to guarantee the continuity of Landsat/ Earth Resource Satellite data needed for BLM to make a complete switch to reliance on satellite data.

For the immediate future, the continuing availability of Landsat MSS data is required for programs that are under way or planned. In addition, BLM has a longer term requirement for data of greater spectral and spatial resolution. At present, the available Landsat data barely meet some BLM requirements. In order to realize the full potential of such capability, data of increased resolution are mandatory. At present, we can only streamline and economize by utilizing Landsat as a sampling frame. in the future, we must provide increasingly detailed data or face a stagnation of the program and a consequent halt in transition to these powerful tools. Thus, both the current multispectral scanner and the future thematic mapper data are of great interest to BLM.

Acquisition of Hardware and Software

As an integral part of the joint BLM-NASA-EROS program, BLM acquired and installed a digital image processing system at the Denver Service Center. This system is currently being used to support inventory projects in BLM. The system includes a complete Earth resources data processing software package. It is projected to have a lo-year lifespan, but is modular in nature to allow for both software and hardware improvements. As the need for Landsat data increase, additional processing capability in terms of other systems or approaches must be considered. For example, BLM anticipates inventorying 30 million acres annually on the single system currently in operation at the Denver Service Center. Depending upon support requirements for BLM inventories this figure will fall far short of the total requirements of BLM. Thus, further acquisition of hardware and software may be necessitated by the transition to Landsat-aided inventories.

Applications of Landsat in the Planning System

The BLM-NASA-EROS wildland vegetation resource inventory project was specifically designed to test and evaluate the use of Landsat data for application in the planning system. BLM conducted a test program in three test sites in Alaska, Arizona, and Idaho, which are representative of the lands managed by BLM. The program was conducted in phases, in which each phase had increasing complexity. In this manner, it was possible to answer basic questions concerning the technology prior to expending funds on subsequent phases, The results of this program were extremely successful, and portions of the technology have been used in BLM. Table B-3 illustrates some of the management opportunity map overlays that are currently being used in the planning system. These particular overlays resulted from the Landsat-aided analysis in the Arizona project and are typical of the requirements of the planning system. Table B-4 illustrates the tabular data that are available as a result of this program. This information is also applicable to the planning system. The true utility of this technology lies in the flexibility of the data base that is developed as part of the analysis. Joining Landsat data with ancillary data in a geographic data base provides a previously unheard-of dimension to the planning system. A typical database may consiste of the following elements.

- computer classes representing land cover from Landsat data;
- slope, aspect, elevation;
- photo interpretation data;
- sources of water;
- road net;
- production for forest, woodland, and rangeland resources;
- ground data;
- administrative units; and
- soil information.

Although Landsat is only one aspect of this broad data base, it is in fact the foundation underpinning other data. From this data base, the types of products listed in table B-3 can be produced. Figure B-3 illustrates a basic map of current vegetation produced from this technology for use in URA. An example of another product of the data base is shown in figure B-4. Depicted here is its use to delineate areas of high potential for Desert Big Horn Sheep habitation. The digital nature of this data base provides a great deal of flexibility. Products can be made at extremely low cost, and they can also be revised in an economical and efficient manner. The data base is also very easily revised as new information becomes available,

Benefits, Budget, and Personnel

The costs of developing the data base from Landsat data are very attractive. By contrast, the process of producing necessary map overlays by hand is labor inten- - sive, time consuming, and is by nature subjective. The study project maintained detailed records of costs, both recurring and nonrecurring. The costs associated

Table B-3.—Management Opportunity (Arizona Strip District)

Management products	Scale	Management parameters	Current use	Potential use
Potential juniper—pinyon cutting/burning areas	1 :126,720	Vegetation: ua percent juniper—pinyon Elevation: 5,000-6,000 ft Slope: 0-15 percent Aspect: within % mile of a road.	Two areas identified for tree use permits	High for EA, AMP, HMP.
Potential blackbrush treatment areas	1 :126,710	Vegetation: high component blackbrush with grass understory Elevation: 4,500-5,000 ft Slope: variable Aspect: north, northeast.	Used in programmatic blackbrush - sagebrush burning EA	High for EA, AMP, HMP, EIS.
Potential antelope habitat	1:126,720	Vegetation: Great Basin desert shrub, plains grassland Elevation: 4,000-6,000 ft Slope: 0-20 percent Aspect: variable.	Being used for HMP	High for HMP, URA, and MFP.
ESL overlay sagebrush treatment areas	1:126,720	Vegetation: 50 percent sagebrush with perennial grass understory Elevation: variable Slope: less than 15 percent Aspect: variable 10-acre minimum.	Available for office use	High for EIS implementation EA's, and AMP's, HMP.
ESL overlay rangeland suitability	1 :126,720	Current production of usable forage above 20 lbs/acre Located within 4 miles of water Elevation: variable Slope: less than 51 percent Aspect: variable.	Available for office use	To prove suitability of allotment.
Potential mule deer summer range	1 :126,710	Vegetation: juniper-pinyon, ponderosa pine Elevation: above 6,000 ft Slope: variable Aspect: variable.	Available for office use	High for HMP, URA, and MFP.
Potential mule deer intermediate range	1 :126,720	Vegetation: variable Elevation: 5,000-6,000 ft Slope: 0-100 percent Aspect: variable.	Available for office use	**High for HMP, URA, and MFP.**
Potential mule deer winter range	1 :126,720	Vegetation: variable Elevation: 3,000-5,000 ft Slope: 0-100 percent Aspect: variable.	Available for office use	High for HMP, URA, and MFP.
Potential burning areas	1 :126,720	Vegetation: sufficient grass understory for natural reseeding Elevation: 4,250-6,240 ft Slope: variable Aspect: variable.	Available for office use	High for EA, AMP, HMP.

Table B“3.—Management Opportunity (Arizona Strip District) (Continued)

Management products	Scale	Management parameters	Current use	Potential use
Potential juniper. pinyon burning areas	1:126,710	Vegetation: juniper-pinyon, 35 to 50 percent, mountain shrub, 7 percent, Mojave Desert shrub, 7 percent Elevation: 5,000-6,000 ft Slope: 0-15 percent Aspect: variable.	Available for office use	High for EA, AMP, HMP.
Potential burning areas	1:126,710	Vegetation: sufficient grass understory for natural reseeding Elevation: 3,250-5,750 ft Slope: variable Aspect: variable.	Available for office use	High for EA, AMP, HMP.

SOURCE: Office of Technology Assessment,

Table B-4.-Grand Planning Unit

Area: 31,688 acres; 12,777 hectares; 2 percent of planning unit

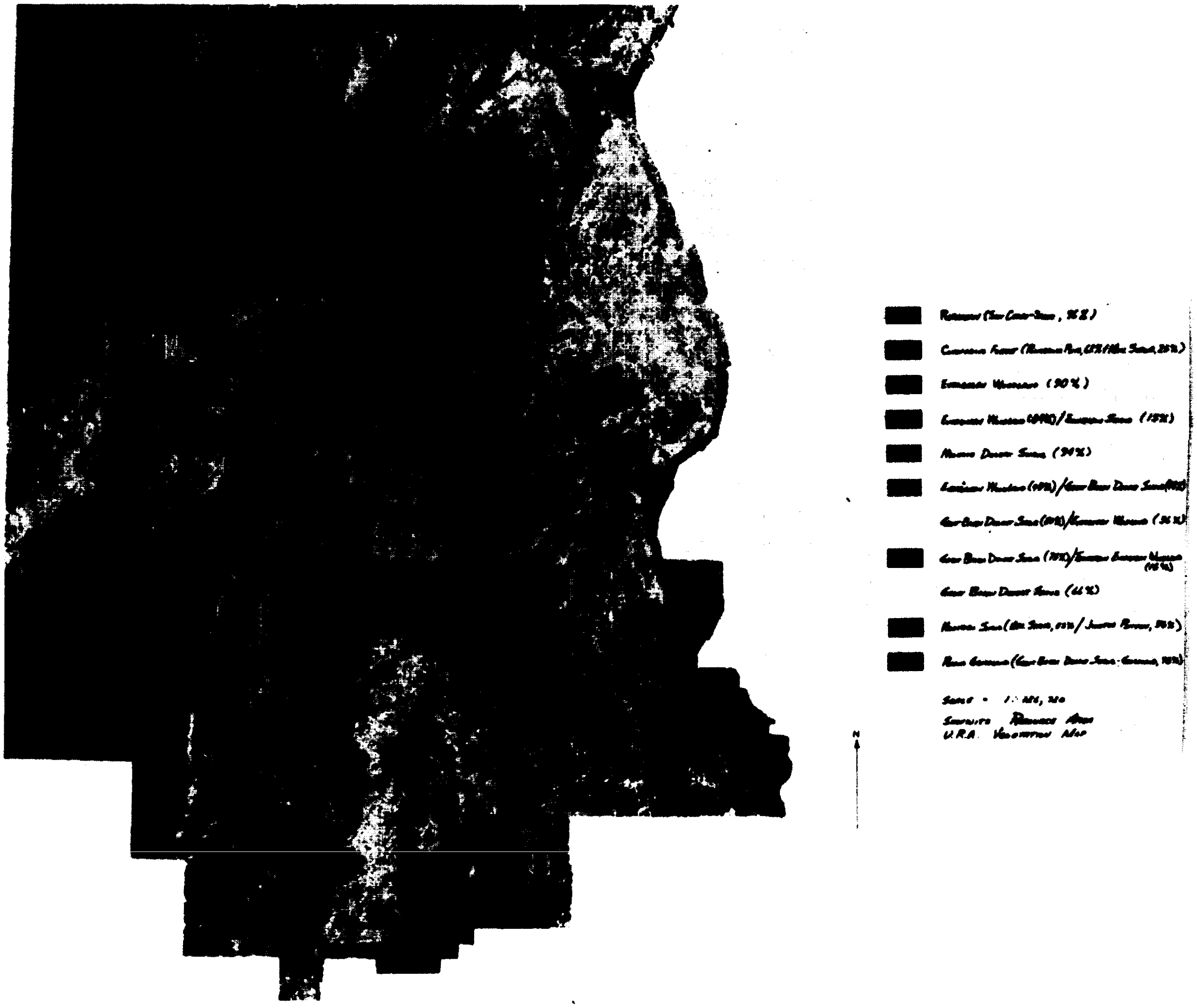
Elevation			Slope			Aspecty		
Class (ft.)	Acres	Percent area	Class percent	Acres	Percent area	Class	Acres	Percent area
3,000	402	1	0-5	22,759	72	NW	2,646	*8*
3,500	771	2	6-10	3,443	11	N	4,510	*14*
4,000	3,101	10	11-20	2,650	8	NE	5,857	*18*
4,500	3,975	13	21-50	2,364	7	E	7,406	*23*
5,000	11,487	36	51-100	439	1	SE	2,434	
5,500	11,249	35	100	33	1	s	2,703	*:*
6,000	681	2				Sw	3,420	11
6,500	22	1				w	2,712	9

Cover type description based on photo data, 212 photo plots

Evergreen woodland	Mohave desert shrub	Great Basin desert shrub	Mountain shrub	Plains grassland
Juniper-pinyon shrub. .. .22	Mixed desert shrub. 1	Big sagebrush 1	Mixed chaparral 1	Grama-galleta-shrub-steppe 1
		Big sagebrush-perennial grass. ...7	Turbinella oak 3	Cheatgrass shrub. ...1
		Big sagebrush-mixed shrub 17		
		Big sagebrush-tree. 8		
		Fourwing saltbush 1		
		Blackbrush 3		
		Blackbrush-tree 2		
		Blackbrush-other desert shrub. ..14		
		Snakeweed 14		
		Little rabbitbrush 4		
Total, percent 22	1	71	4	2

SOURCE: Office of Technology Assessment.

Figure B-3.–Current Vegetation Map

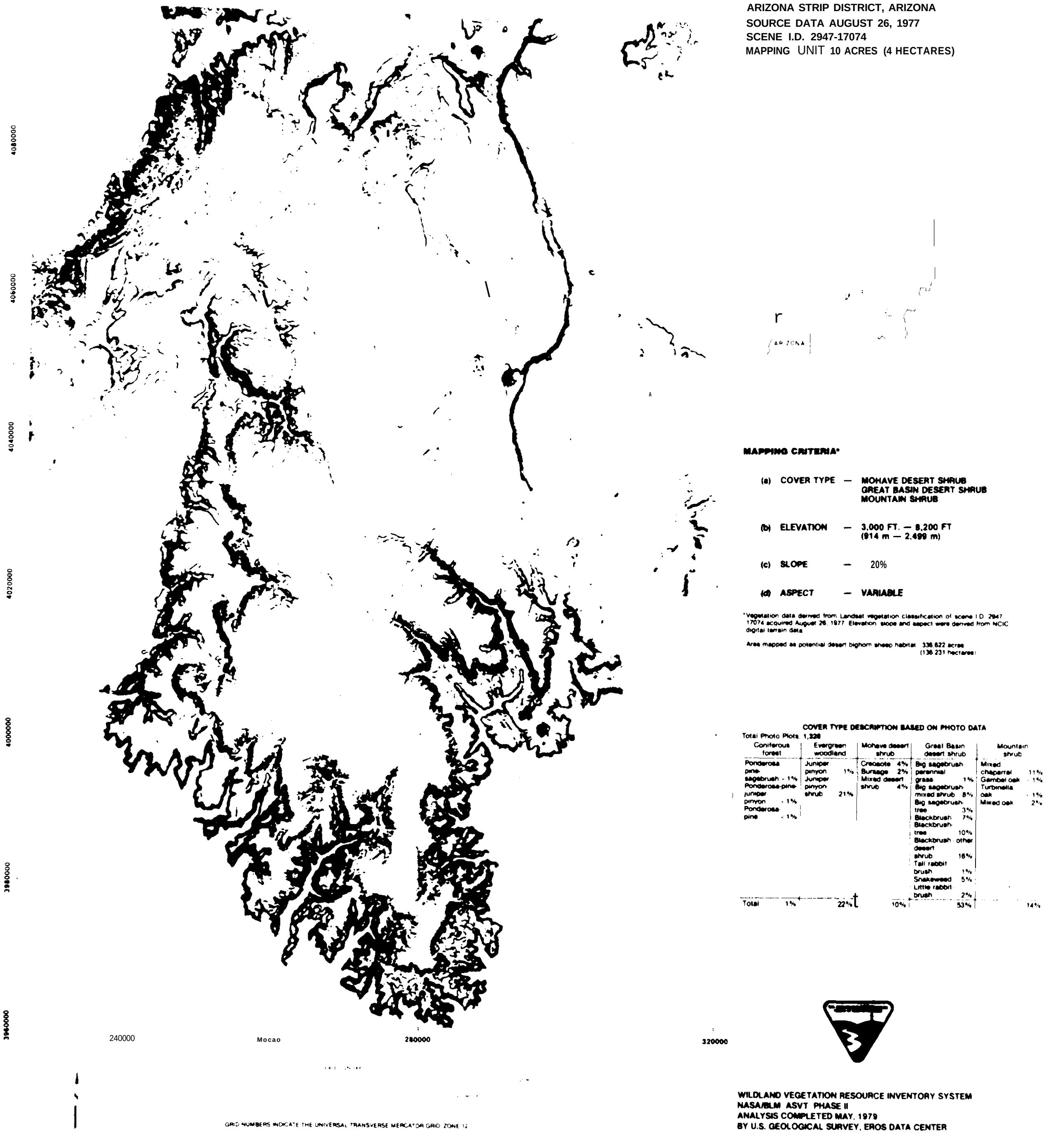


with producing the detailed maps in the project were $0.07 per acre. This includes establishing the data base, which includes Landsat classification results, digital terrain data (elevation, slope, and aspect), photo interpretation results, ground data collection results, and digitized ownership boundaries. The geographically referenced data base allows extraction of subsequent information by coordinates of any scale and in any practical form. The cost associated with this secondary data extraction is $0.0006 per acre. These costs are in 1980 dollars and are subject to a number of considerations. For example, it is possible to study larger areas without increase in the unit cost per acre. Similarly, the complexity of the area could cause an increase in the unit cost.

Potential Applications of Landsat to SVIM

The BLM-NASA-EROS wildland vegetation resource inventory project concluded that using Landsat data has the potential to reduce the cost of SVIM inventories. Consequently, a program was conducted in fiscal year 1981 to test and evaluate the feasibility of this concept. The objective of the study was to determine the utility of Landsat and ancillary data when combined with soils data in generating site writeup area

Figure B.4.—Potential Desert Bighorn Sheep Habitat



ARIZONA STRIP DISTRICT, ARIZONA
SOURCE DATA AUGUST 26, 1977
SCENE I.D. 2947-17074
MAPPING UNIT 10 ACRES (4 HECTARES)

MAPPING CRITERIA*

(a) COVER TYPE — MOHAVE DESERT SHRUB
GREAT BASIN DESERT SHRUB
MOUNTAIN SHRUB

(b) ELEVATION — 3,000 FT. — 8,200 FT
(914 m — 2,499 m)

(c) SLOPE — 20%

(d) ASPECT — VARIABLE

*Vegetation data derived from Landsat vegetation classification of scene I.D. 2947-17074 acquired August 26, 1977. Elevation, slope and aspect were derived from NCIC digital terrain data.

Area mapped as potential desert bighorn sheep habitat 336,622 acres
(136,231 hectares)

COVER TYPE DESCRIPTION BASED ON PHOTO DATA

Total Photo Plots: 1,328

Coniferous forest	Evergreen woodland	Mohave desert shrub	Great Basin desert shrub	Mountain shrub
Ponderosa pine-sagebrush < 1% Ponderosa-pine-juniper-pinyon < 1% Ponderosa pine < 1%	Juniper-pinyon 1% Juniper-pinyon-shrub 21%	Creosote 4% Bursage 2% Mixed desert shrub 4%	Big sagebrush-perennial grass 1% Big sagebrush-mixed shrub 8% Big sagebrush-tree 3% Blackbrush 7% Blackbrush-tree 10% Blackbrush-other desert shrub 16% Tall rabbit brush 1% Snakeweed 5% Little rabbit brush 2%	Mixed chaparral 11% Gambel oak < 1% Turbinella oak < 1% Mixed oak 2%
Total 1%	22%	10%	53%	14%

WILDLAND VEGETATION RESOURCE INVENTORY SYSTEM
NASA/BLM ASVT PHASE II
ANALYSIS COMPLETED MAY, 1979
BY U.S. GEOLOGICAL SURVEY, EROS DATA CENTER

(WA) maps for SVIM inventories. A test site in Wyoming where SVIM data collected by traditional means is available for quality and cost comparison has been identified for this program. The project was conducted in two phases. Part one tested and evaluated the hypothesis on a site that is covered by a SVIM inventory. The results of this test are not yet available. However, once feasibility is demonstrated, the process will be defined in detail and implemented in a new area. Careful cost records will be maintained so that a definite conclusion can be reached on cost savings.

Initial studies indicate a potential for significant savings in field work and product preparation. Savings in personnel in the form of time and work efficiency are possible. Once again, a new mix of personnel (technologists/resource specialists) will be required, but these will be persons already involved in these programs. The budget appropriated for the test phase of this program is approximately $100,000.

Effects of Programs Utilizing Landsat Data

Technical Impacts

The most substantial technical byproduct of this program has been the acquisition by BLM of a complete off-the-shelf remote-sensing digital image processing system and associated software. The acquisition of this equipment at a cost of approximately $500,000 (cost of equipment and facilities) represented a sharp departure from previous philosophies in the organization, It was a recognition by management of the need to bring space age technology to bear upon the problems associated with resources management.

As the program has evolved, it has also become obvious that there is a growing potential requirement for a distributed system. BLM field offices will also need to be capable of conducting routine analysis of Landsat data. This will be a function of schedules, availability of resources, and the individual field office technological capabilities. In addition, the field offices will need to reach and revise their Landsat data base, It may also be useful for BLM offices to use the processing capability at the EROS Data Center (EDC). Similarly, BLM Alaska will use the EDC Field Office system in Anchorage.

Preliminary tests of the system have been very positive. Its products have been determined to have direct application in management activities. They have also been found to be as accurate, and in some instances more accurate, than those that are produced by more conventional means. Furthermore, the products are more easily produced and, as a result, more readily available to field personnel. The geographically referenced digital data base containing Landsat data and ancillary information has proved to be an extremely valuable management tool.

The importance of the geographically referenced data base that results from this technology is just beginning to be realized. The accuracy of the information, the timeliness with which products can be produced and revised, the ease with which the data base can be revised, and the low cost to use the data base as well as its low initial cost are all factors which will generate increased use of this technology.

Different Personnel Requirements

As a result of this program, BLM has experienced an influx of technical specialists who have complemented the existing BLM expertise. These individuals consist of foresters, botanists, range conservationists, geologists, systems analysts, physicists, etc., who by virture of formal education or work-related experience have become specialists in the field of remote sensing. Table B-5 provides a list of individual technical skills now found in BRS (new organization resulting from this program) at the Denver Service Center (DSC). Table B-6 is a list of individual skills supporting the BLM remote-sensing R&D programs. An unusual skill mix exists in these groups. Such a skill mix is mandatory in order to: 1) be responsive to BLM resource management requirements, and 2) implement successfully a technical program at the field level. The advent of this technology has also affected operations and personnel at the field level. Most BLM offices that become involved in the program appoint remote-sensing coordinators who are normally persons within the existing organization such as soil scientists, foresters, and range conservationists. Once selected, these persons receive intensive training in the technology and then work in concert with their BLM counterparts at DSC for the duration of the project.

Economic Effects

To compare overall planning system costs with Landsat costs is not realistic. Since Landsat data are

Table B=5.—Individual Skills Supporting BLM Remote-Sensing R&D Programs

Remote Sensing Skills—Branch of Remote Sensing
Forestry
Geology
Wildlife Biology
Botany
Remote-Sensing Skills—TGS Contractor
Forestry
Earth Resources
Biometrics
Range Science
Environmental Monitoring
Wildlife Biology
System Analyst
Programing

SOURCE: Bureau of Land Management.

Table B-6.—Remote-Sensing Skills—Division of Scientific Systems Development

Remote-Sensing Skills—Division of Scientific Systems Development
Geology
Remote-Sensing Science
Statistics
Cartography
Computer Systems
Physics

SOURCE: Bureau of Land Management

utilized to support the planning system, only those parts of the latter which are replaced by methods using Landsat data may be considered. A small example that illustrates potential savings is the generation of a habitat map involving vegetation, slope, aspect, elevation, disturbance corridors, and sources of water at a scale of 1:126,720 (1/2 inch = 1 mile) for a 2 million acre area. This would cost on the order of $500, if the Landsat geographic data base were used, The same product produced by hand in the traditional manner would typically cost at least $2,500. To produce the map by traditional means would take a matter of weeks, while the Landsat-derived map could be produced in a matter of hours (from an established data base). The former would be subject to the bias of the analyst, while the latter would be objective within the criteria specified. In addition, the traditional map would be difficult, costly, and time consuming to revise, but the Landsat map could be quickly modified and regenerated, The Landsat map would also be inherently more accurate and could be legally defended if required.

In another example, BLM proposes to streamline the process of SVIM inventory by incorporating Landsat data with SVIM. Such action is expected to reduce costs by approximately 20 percent.

Institutional Effects

BLM Landsat remote-sensing program has produced some institutional benefits, It has caused exchange of information and cooperative projects that are still in progress between BLM and other Federal, State, and local governments. Such exchanges are also occurring between BLM and industry and BLM and the academic community. Examples of some of these are:

- Geological Survey, National Park Service, NASA, Forest Service, Corps of Engineers, Soil Conservation Service, and Bureau of Indian Affairs.
- University of California–Berkeley, Riverside; University of Arizona, and University of Alaska.
- Raytheon, IBM, Geospectra Corp., ESL, Inc., and Technicolor Graphic Services.

It is estimated that 3 work years have been dedicated to coordinating and managing these efforts in the last 5 years.

International Effects

The current programs have not affected world trade, prices, or the competitive position of the United States. Nor have they affected the current system on international land use policy formulation. However, they have led to some international cooperation between BLM and Mexico and BLM and Australia. In a recent project, BLM provided extensive support and cooperation to Australia. An Australian scientist worked at the BLM facility in Denver to do a Landsat analysis on the BLM image processing system. BLM is also supporting a project between the United States and Mexico to map desertification indicators in two test sites in Mexico and one in the United States.

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Appendix C

FOREIGN AGRICULTURE SERVICE, DEPARTMENT OF AGRICULTURE, CROP CONDITION ASSESSMENT*

Introduction

The Foreign Agriculture Service (FAS) is one of two Federal agencies that can be said to be utilizing remote-sensing satellite data in a daily operational format. Its unique qualities as an operational program have been and are that, although like many other Government users, it acquires, processes, and analyzes repetitive Landsat data, FAS is the only agency routinely having a requirement to produce a product in *near real time.*

FAS has been notably successful in managing the transition from limited use of data derived from a research and development (R&D) system to full integration of data from an operational system. If the R&D system is built and tested by one agency, but the operational system is to be managed by another, then appropriate cross-agency responsibilities for managing the transition must be devised. In addition, the hardware and software incorporated in the R&D system are usually more advanced than what the user agency requires or can even use. The success of FAS in effecting this transition provides a model that the Federal Government, as well as State and municipal governments, might follow.

The FAS Mission

The primary FAS mission is to develop, maintain, and expand foreign markets for U.S. agricultural commodities. To accomplish this mission, FAS maintains a worldwide agricultural intelligence and reporting system to provide timely and accurate information on world agricultural production and trade. The information provided by FAS enables U.S. farmers and traders to adjust to changes in world demand for U.S. agricultural products. The information is also used by the Department of Agriculture (USDA), other Federal agencies, the Congress, and others in the formulation of foreign market development and export sales policies, and in developing strategies for negotiating international trade agreements.

Product

Current information covering principal agricultural commodities that has been developed by USDA analysts is made available to the public through the following kinds of publications:

- FAS *circulars* for major commodities (scheduled and unscheduled). These circulars contain as a minimum the current official USDA acreage, yield, and production estimates.
- Weekly *roundups* that provide interim updates between the release of the scheduled circulars, particularly with regard to unusual or unexpected events which may impact production.
- *Foreign Agriculture Magazine* (monthly) that publishes articles on foreign agricultural matters of general interest.

The scheduled “circulars” and the “Weekly Roundup” reports are released on a predetermined schedule to provide equal access by all users. The current FAS remote-sensing program was initiated in 1973 with the conception of the large area crop inventory experiment (LACIE). LACIE was a joint cooperative effort among USDA, the National Aeronautics and Space Administration (NASA), and the National Oceanic and Atmospheric Administration (NOAA). The goal of LACIE was to develop, test, and evaluate a system for predicting foreign wheat production through the use of Landsat satellite data, weather and agricultural data, and advanced data processing technology. LACIE began with the signing of an interagency memorandum of understanding in 1974, and ended in 1978. Each participating agency contributed funds and personnel to the project.

The project was directed by a three-agency, high-level, executive steering group, with LACIE project management assigned to a project management team (PMT) made up of senior technical managers from each of the agencies. The NASA technical manager was responsible for day-to-day operations, but management decisions were made by the joint PMT.

The LACIE approach was to: 1) develop wheat area measurements from analysis of randomly selected Landsat sample segments; 2) estimate yield through use of weather-related regression yield models; and 3) multiply area by yield to develop regional and country production estimates.

The USDA LACIE project team developed a set of USDA user requirements based on 1) interviews with FAS commodity analysts, embassy attaches and management, 2) reviews of the FAS operational forecasting systems, and 3) discussion with users of FAS global crop information. These requirements were evaluated

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*This report is a condensation of a larger report submitted to **OTA as a case study. The aid of FAS in contributing to this assessment is gratefully acknowledged.**

for accuracy and timeliness and presented to the executive steering group. However, because the then-current Landsat technology (ERTS 1) would not fully meet USDA user requirements, the requirements were modified, at the insistence of one of the technical agencies, to a level thought to be achievable.

Results

During its lifetime, LACIE produced wheat production estimates as follows: U.S. Great Plains in 1975, **1976,** and 1977; Canada in 1976; two Soviet Union indicator regions in 1976; and the entire Soviet Union in 1977 and 1978. Generally, all of the winter wheat and the Soviet spring wheat estimates were acceptably close to official USDA figures. However, the U.S. and Canada spring wheat estimates failed to meet the LACIE accuracy objectives. The poor performance on spring wheat was largely due to the compressed growing season **for spring wheat and the presence of other "confusion crops."** The results of LACIE were reported at a symposium that was held at the Johnson Space Center in October 1978.

Hardware and Software Considerations

Technology transfer in any environment carries a certain element of risk. The relative novelty of space data collection and analysis for foreign agricultural applications significantly increased this risk factor. Therefore, a policy was adopted that was calculated to minimize financial risk to USDA while retaining maximum flexibility to deal with technological contingencies. The three major elements of this policy were:

1. All **hardware and software procured to support the design** would be commercially available "off-the-shelf" and vendor-maintained.
2. Discrete functions were designed to operate on a single mini computer, yet retain the capability for interfunction communications.
3. All **application** programing was to be modular and would conform to Federal and Department standards for information processing.

Management Approach

FAS applied management by objective and structured decisionmaking to the transition from R&D to a user test and subsequently to full operation. The professional staff was involved in the technology transfer process, starting with the initial planning process. Without this involvement, successful transfer of technology would not have occurred.

Long-Range Planning

The long-range (5-year) management plan guided all activities in the transition to operational application of space-acquired data. Commencing in 1978, a series of yearly management plans were initiated. These plans contain, on a year-by-year basis, the next level of resource detail and task description.

Major problerns.-The problems encountered in the transition to space-aided data collection were not just technical in nature, but encompassed the entire scope of institutional reactions toward implementing a new technology:

External:

- timely receipt of Landsat data from NASA
- timely receipt of meteorological data from the Air Force; and
- lack of R&D assistance to transfer activities

Internal:

- education of end user; and
- establishment of means to provide FAS meteorological data from the World Food and Agricultural Situation Board within 24 hours.

Continuing problems. –R&D support to technology transfer activities, and physical separation of analytical functions from the end user of a product. The data base generally available to the FAS **analysts is:**

- **Landsat—3 days to 3 weeks after acquisition;**
- **weather station reports-24 hours after receipt by NOAA; and**
- **environmental satellites—34/48 hours after acquisition.**

These data are further supplemented, where and when available, from on-ground observations (ground truth) for areas of interest, but these inputs are limited and in some cases unavailable, Examples of the analytical products derived from this variety data sources are:

Narrative assessments of:

- crop and pasture conditions and probable impacts on production;
- outlook for water for irrigation; and
- planting and/or harvest conditions.

Maps that show:

- crop stress lines;
- plots of vegetative index numbers, including comparison to baseline years;
- snow cover, temperature, and potential winterkill lines; and
- precipitation and soil moisture, and deviation from baseline years.

Color displays:

These use several media, including photographs, color graphics terminals, video tape recorders, and overhead projectors. Examples of color products are:

- analyzed Landsat data;
- current and historical soil moisture;
- current and average crop calendars;
- soils information; and
- daily precipitation for selected 10-day periods,

FAS management by objective requires the development of long-range objectives as a basis for defining longer term goals, which in turn form the basis for the planning documents described.

Management Planning

This activity builds on the long-range planning for the transition from R&D to an operational system. The 5-year management plan, originally developed to guide the transition, is reviewed annually in light of FAS objectives and requirements, revised as necessary, and presented to management for approval.

Short-term. -An annual management plan translates the appropriate portions of the 5-year plan into a plan for the coming fiscal year that contains tasking schedules and resource requirements.

Contingency Planning

This process identifies potential barriers to the orderly progress of crop estimation and estimates the probability of their occurrence. Plans are then developed to avert or minimize the consequences.

An appropriate example of such a situation is the anticipated lack of multispectral scanner (MSS) data between the demise of Landsat-3 and the operational readiness of Landsat-D. In anticipation of such an event, a contingency plan was developed which involves the use of the **NOAA-6 and NOAA-7 satellite sensors as alternate data sources. Correlations between the Landsat and NOAA-6 data, and a hardware system to accept, process, and analyze the data are currently under development.**

Budget Planning

In addition to management and operations planning, the Crop Condition Assessment Division (CCAD) had developed a long-range financial plan that projects CCAD'S operations and systems replacement costs for the next 5 years. This 5-year financial plan is updated annually. The plan is used to prepare realistic CCAD cost estimates as input to the FAS and USDA budget process, and to develop procurement strategies for replacing computer systems as they become obsolete.

Problems

The problems encountered in developing and implementing the operational system are essentially the same as those encountered during the transition from R&D to operational status. However, their effect is even greater, given the requirement to provide short turnaround data analysis and reporting. Again, problems can be divided into those internal to FAS and those that are external:

Negotiating arrangements with NASA to:

- Furnish Landsat data within 48 hours after collection. (To date, NASA has been unable to meet FAS timing requirements.)
- Accept and process FAS orders for repetitive and one-time Landsat data collection.

Unanticipated changes in Landsat data format. Originally, NASA announced that the data would be delivered in a high-density digital product tape (HDDT), on which radiometric and geometric corrections and resampling had already been accomplished. Then, NASA and the U.S. Department of the Interior (USDI) jointly announced that the standard tape format would be changed to HDDT archival tape, on which only the radiometric corrections had been made. As a result, FAS was forced to divert approximately $250,000 from its planned system enhancement to modify the scene processing unit to accommodate the new format.

Inability of Landsat-D to provide full geographic coverage. The proposed Landsat- D, with its dependence on the tracking and data relay satellite system (TDRSS) will not provide timely (24-hour) coverage for India, Pakistan, and a major portion of the U.S.S.R. spring wheat region. These areas are critical to FAS. USDA repeatedly requested installation of wide-band tape recorders on Landsat-D and D' to ensure full geographic coverage. However, the tape recorders are not included in the planned system configuration.

Strong probability of a lengthy Landsat MSS data gap between the end of Landsat-3 and the operational readiness of Landsat-D (this has already occurred). FAS **and USDA were unable to alter NASA's schedule, which seemed to be dictated** more by a preoccupation with technical problems with the Thematic Mapper than by the pressing need of users for continuity of MSS data.

The uncertainty about MSS data continuity required the diversion of analytical resources to development of techniques to use NOAA's environmental satellites as an alternative data source.

Lack of rapid turnaround R&D assistance in developing, testing, and implementing techniques to processs and analyze environmental satellite data. This slowness seemed to stem from the R&D community's perception that its role was to carry out basic and long-term research as opposed to applied research to solve pressing problems.

Internal:

- establishing system credibility with FAS commodity analysts and others.

issues outstanding:

- delays in delivery of Landsat data;
- probability of an extended break in Landsat data continuity;
- lack of timely data for India, Pakistan, and part of Soviet Union through the 1980's; and
- lack of R&D support to resolve near-term operational problems.

Improvement in Information

For the past 2 years, the project has been analyzing space-acquired meteorological data and providing condition assessments to FAS commodity analysts. These reports are not used by the agency as "stand alone" reports, but are used as additional input in formulating the agency's country-by-country production and demand forecasts. Because the reports have only been available for 2 years and because they are integrated into multisource reports, it is impossible at this time to quantify improvements to the FAS information system. However, qualitative improvements through enhancements to the FAS analytical process are evident. Examples of services that improve the analysis **and** increase confidence are as follows:

- early warnings of situations that may affect agricultural commodity production and assessments of probable impact;
- continuous monitoring of conditions in foreign high-risk/high-priority regions throughout the entire crop production cycle, and issuance of periodic assessment reports; and
- confirmation (or denial) of reported situations affecting foreign crops.

Availability to analysts and embassy attaches of information in gridded data base relative to:

- moisture available to plants at planting time and throughout the growth cycle and deviation from baseline years;
- crop growth stage at any specified time, and deviations from baseline;
- daily temperature/precipitation, and deviations;
- soils/climate information for areas of interest; and
- agricultural acreage, yield and production statistics at subcountry/province level.

Landsat and Successor Systems Requirements

Ground Data Handling.-This function is the cornerstone of any operational use of data acquired from space. The FAS technical requirements relative to this function were first stated in the Department's user requirements document, which was developed during LACIE and subsequently reaffirmed in informal correspondence between **USDA and NASA/NOAA. Additionally, the requirements were also documented as input to the recent Integrated Remote Sensing Systems Study (IRS[3]), These requirements are as follows:**

Data Delivery

Data delivery requirements in support of **FAS operations are as follows:**

- **HDDT** in Product ("P") format with radiometric and geometric corrections applied. Nearest neighbor resampling is preferred.;
- delivery systems should not introduce data errors over and above those inherent in the collector; and
- pass-to-pass registration of frame data is a minimum requirement. Header data for registration to a given cartographic base is also considered a requirement.

Data Timeliness

Timeliness of data is a critical technical requirement for FAS. The quantification of this requirement is specified below:

Ž All data collected by the 4-band MSS are to be made available for processing by FAS within 48 hours after acquisition by the satellite.

All special FAS requests to activate the collector over areas routinely scheduled for coverge must be scheduled within 24 hours after receipt of the request.

Data retransmission required because of errors or omissions must occur within a 12-hour period regardless of error source.

Data Continuity

The requirement for data continuity has two discrete elements: day-by-day processing and delivery to the user; and data coverage comparability between space platforms, with no gap in time between operational readiness of successive collection platforms. Each of these FAS requirements is summarized as follows:

Day-by-Day Data Receipt (reliability)

- total daily data collection must be processed and delivered to FAS within the timeliness criterion; and
- data backlogs cannot be tolerated within the scheduled operations and resource base of FAS.

Data Gap

The data gap potential is the most worrisome situation a user of satellite data can face. In this context FAS has initiated and supported the following requirements:

- A space platform with fully operational MSS to be in orbit at all times;
- the 4-band MSS with on-board wide-band tape recorders to be continuously operated through the 1980's;
- a single satellite (collector) operational with a backup available for launch to assure data continuity; and
- total world coverage capability with *no* "black holes," or data gaps due to other priorities as are expected to occur with Landsat-D and TDRSS.

Experience during the past 2 years of operation have reinforced these technical requirements. Current FAS analytical capabilities are facing serious degradation because the minimum requirements defined in this section have not been satisfied, and apparently will not be satisfied during the Landsat-D system lifetime.

Personnel Impact

No FAS functions or positions will be eliminated as a result of the current system. However, automation and the integration of new data sources into the analytical and decisionmaking process will relieve senior analysts to concentrate on additional tasks that have been levied upon commodity programs by Congress and the executive branch without a compensating increase in personnel.

International Impact

It is not possible at this time accurately to determine the dollar value that changes in the system will have on the dollar value of U.S. exports, world prices, U.S. competitive position and economic policy. However, over the next 4 to 6 years, given a "free market" environment, the real value to the United States of current foreign crop information will increase dramatically. The magnitude of this value will depend in a large measure upon the U.S. policy concerning export of space-related technology to nations who compete for U.S. foreign markets. A policy of open and equal access to agricultural data collected by U.S. space platform and related technology could tend to reduce the U.S. competitive advantage in the world market and perhaps "stagnate" our level of exports. It could also permit other nations to compete in markets that have been traditionally dominated by the United States. This situation may not be acceptable given the need for expanded U.S. markets to offset the increasing dollar flow for oil imports. This is a national policy question that FAS and USDA cannot resolve. However, national policy on the international availability of U.S. space technology and/or data collected from space will have a significant impact on the value to the United States of improved agricultural information.

International Cooperation

The current system and the preceding R&D have stimulated interest in bilateral cooperation in the exchange of technology. The following will serve as an example:

In early 1977, the President of Mexico received an in-depth briefing by FAS of LACIE results and USDA application of remote-sensing technology. This briefing led to agreements in principle between the Secretary of Agriculture and the Mexican Minister of Agriculture later to exchange mutually beneficial technology. FAS and Mexican technical managers developed a plan for an exchange of technical staff between the Ministry of Agriculture and FAS (CCAD).

NASA's International Affairs office was represented at all meetings in Washington and Mexico City. One problem encountered in these planning sessions was NASA's insistence that Mexico purchase a ground receiving station even though all areas of interest to the Mexican Government were routinely collected to meet U.S. data requirements and processed through NASA's Goddard Space Flight Center. This problem could have been resolved, but factors external to USDA and NASA halted further communications toward negotiations of a working bilateral agreement.

Given the increasing awareness of the need for closer ties between the United States and Mexico, it would seem to be in the U.S. interest to reopen negotiations that would lead to a bilateral agreement regarding agricultural applications of space technology.

Appendix D

MATERIALS SCIENCE AND ENGINEERING IN MICROGRAVITY*

Introduction

Two hundred miles above Earth, unfiltered solar radiation, a near-perfect vacuum, and temperature extremes ranging from –200° to +200° F exist in an environment almost free of gravitational force. The recent interest in materials processing in space (MPS) has its origin in the belief that the unique attributes of this environment may have important scientific and commercial applications.

With the exception of microgravity, the attributes of the space environment can be duplicated on Earth in sufficient quantities and duration to investigate their extended effect on processes and materials. Though microgravity can be simulated by using airplanes, sounding rockets, and in some instances magnetic fields, such simulations are generally of short duration, involve only limited quantities of test material, and often introduce complicating factors such as vibration and impurities. The long-term microgravity environment of space introduces a new dimension in controlling process variables such as temperature, composition, and fluid flow. Through this experimentation, new opportunities for understanding and improving ground-based production methods will be created, and, where practical and economical, select materials may be produced in space.

Scientific Status of Materials Processing in Space

Microgravity Alterations of Processing Phenomena

By using the long-duration, microgravity environment of an orbiting spacecraft, new manufacturing processes can be designed. On Earth the theoretical performance characteristics of materials are inhibited by such gravity-induced phenomena as convection, segregation, buoyancy, and sedimentation. These phenomena function in the following manner:[1]

Convection. The spontaneous stirring and mixing that occurs as currents flow between temperature gradients in a liquid or gas are unpredictable and chaotic, and can lead to unwanted structural and compositional differences in solid material. Both crystal growth and solidification processes are enhanced if convective disturbances are suppressed. The microgravity of space should provide a means to suppress convective phenomena.

Sedimentation/Buoyancy. On Earth, gravity causes heavier components to settle in a mixture while less-dense materials rise. Sedimentation and buoyancy complicate manufacturing techniques for alloys of different density elements and for composite materials. In microgravity, lighter density materials will remain in suspension for indefinite periods of time, thereby allowing the processing of homogeneous composites and alloys where the constituents have large density differences.

Hydrostatic Pressure. Hydrostatic pressure puts a strain on materials during solidification. Certain crystals are sufficiently dense and delicate that they are susceptible to strain under their own weight at growth temperatures. Such strain-induced deformations in crystals degrade their electro-optical performance. In microgravity, heat-treated, melted, or resolidified alloys might be developed free of deformation by coating the machined shape with a thin oxide skin, serving as a mold.

Container Effects. Containerless processing eliminates problems of container contamination and wall effects, often the greatest source of impurities and imperfections while forming molten material. In microgravity, a material may be melted, manipulated, and shaped, free of contact with a container or crucible by using acoustic, electromagnetic, or electrostatic fields. Surface tension would hold the material together in mass, a force overpowered hereon Earth by gravity.

MPS Product Applications

In general, the MPS program is interested in studies of process parameters to enhance control and productivity in Earth manufacturing, to prepare limited quantities of precursor materials to provide baseline or reference data, and to develop methods unique to the space environment by which materials can be prepared. All these research tasks rely upon the range of process parameters being extended through the reduction of gravity.

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*McDonnell Douglas, the Materials Processing in Space Projects Office of NASA, and TRW each provided a case study for this appendix. Their aid is gratefully acknowledged.

[1] See generally: L. K. Zoner, "Materials Science and Engineering in Space, " in *Commercial Operations* in Space, *1980-2000,* 18th Goddard Symposium, AAS, vol. 51, Science and Technology Series, 1981, pp. 20-26; K. Moritz, "In the Realm of Zero-G," *TRW Systems and Energy,* winter 1978, pp. 16-24.

Examples of potential applications derived from MPS research are as follows.

Crystal Growth[2]

Melt growth is the most widely exploited technique to produce high-technology, single-crystal materials for semiconductor chips used in large-scale integrated circuits for communications and computers. Chemical homogeneity, which will maximize electrical performance, is believed possible through microgravity processing. Commercially valuable crystals for sensitive infrared sensors, most difficult to grow on **Earth, may be enhanced by melt growth in a microgravity** environment.

As a variation of melt growth, float-zone growth techniques are widely used to produce crystals such as doped silicon for semiconductors and solar cells. Although large, efficient crystals are grown commercially with this process on Earth, gravity does limit the size and type of crystals that can be produced and introduces growth rate fluctuations that cause chemical inhomogeneities that necessitate cutting the crystal into small chips for high-performance applications.

Solution growth of crystals in the MPS program emphasizes creation of room-temperature, infrared detector materials, and gallium-arsenide (GaAs) semi-conductors for a wide range of applications from microwave devices to computers and solid-state lasers. Infrared defectivity of current available material is constrained to about 20 percent of the theoretical limit because of gravity-influenced growth defects. GaAs semiconductors can be readily grown on Earth, but with considerable imperfections,

The absence of gravity opens new possibilities for the growth of large, flat, pure crystals by vapor technique; therefore, the MPS program includes the investigation of $\mathrm{Hg1}^2$ nuclear detector crystals that can be used at ambient temperature. Because the crystal has a layered structure, self-deformation during growth in sizes under 1 g is believed to be an important factor in producing dislocations that degrade the performance of the crystal as a nuclear-energy detector. The growth of such a crystal in microgravity could eliminate such strains at the growth temperature.

Solidification[3]

Control of the solidification of metals and alloys is the key element in the field of metallurgy. Gravitational effects, such as buoyancy-driven convection of the melt or sedimentation, can greatly influence the structure of metals and alloys. Directional solidification in microgravity allows complicated shapes, such as turbine blades, to be melted and directionally resolidified to increase axial strength while using a thin oxide skin to maintain the shape. Additional interest is based on the potential of approaching the theoretical maximum magnetic strength of materials that are 10 times higher than currently realized on Earth.

Another group of potential candidates for in-space production is that of miscibility gap alloys. These alloys defy preparation on Earth in bulk quantities because of gravity-driven effects that cause the materials to segregate upon solidification. There are some 500 such combinations of materials that have a liquid-phase miscibility gap. Processed in microgravity, these materials might have such diverse applications as electrical contacts (as replacements for silver and gold) and self-lubricating bearings.

Solidification kinetics in the casting of alloys under nonterrestrial conditions can produce fine-grained structure in the interior of a casting. This phenomenon could have application in common products such as iron engine castings.

Undercooked solidification is the rapid quenching of molten materials at temperatures well below their freezing points. By containedess processing in microgravity, a vast array of materials is expected to be processed in the amorphous state, thus extending the materials properties available to mechanical and optical designers. Enhanced glasses manufactured by means of this process could improve their energy-transfer efficiency for applications such as laser hosts. In addition, such studies may shed light on methods for obtaining superconductors that work at higher temperatures.

Containerless Processing

Containerless processing may permit the creation of amorphous (glass) materials that cannot be made on Earth, and may allow the analysis of molten materials at temperatures that would exceed the melting point of crucibles on Earth. By elimination of nucleation associated with container walls, it should be possible to extend the glass-forming range of many materials, including some metals, resulting in new and unique glasses with exotic properties. An application of this process is in the production of ultrapure glass used in optical waveguides for high-frequency communications. Other possible applications are fusion-**energy lasers, fiber optics communications, cable networks, and self-focusing lenses.**

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[2] S. Waters, "Tapping the Resources of a New Continent, " Part 1—Materials Processing, *Mechanical Engineering,* June 1981, pp. 26-39.

[3] S. Solomon, "Factories in Space," *Science Digest Special,* September/October 1980, pp. 58-61, 114,

[4] N. J. Barter, "Materials Processing in Space, " Impact for the 1980's–Conference on *Selected Technology for Business and Industry,* May 14-15, 1980, pp. 11-16,

Fluids and Chemical Processes[5]

On **Earth, fluid and chemical processes are affected by gravity-driven convection or sedimentation. Microgravity eliminates these effects, thereby allowing components to be isolated for study with a** degree of freedom not otherwise possible.

A potential application of this technique would be the production of monodisperse latex spheres in space. These spheres are too large to be grown by polymerization and too small to be sized by microsieving on Earth. Because of the absence of sedimentation in microgravity, these latex spheres might be mass produced from a polymerization process while in suspension. These spheres, available only in research quantities, are used in calibrating electron microscopes, light-scattering devices and filters, in the measurement of pore size in membranes, and in serological tests for a multitude of diseases.

The biomedical applications of microgravity such as electrophoresis, isoelectric focusing, phase partitioning, suspension cell culturing, crystallization of macromolecules, and blood flow (rheology) processes will also be evaluated in the MPS program. Application of these techniques in biomedical sciences could lead to production of human insulin; purification of hemopoietic stem cells for treatment of certain types of leukemia; or production of collagen, used for artificial corneas, artificial skin for wound and burn treatments, and for membranes to aid i n cardiovascular and orthopedic surgery.

Status of MPS Technology

History of the MPS Program

The space processing program presently sponsored by the National Aeronautics and Space Administration (NASA) germinated in the mid-to-late 1960's,6 fostered by the need to master propellant characteristics, fire control, and the assembly of structures in space–elements all essential to manned spaceflight. Propellant requirements of the Apollo lunar landing program stimulated research on the effects of surface tensions and inertia in partially filled containers. Similarly, interest in on-orbit repair and assembly required engineering studies of brazing and welding phenomena under microgravity conditions.

In the course of these investigations, it was found that unrestrained liquid masses would form large free-flying globules, that vapor bubbles could grow virtually without limit in boiling liquids, and that flames quickly become blanketed with their own combustion products. These effects of weightlessness were first treated as problems in the engineering of spacecraft systems, only later to be recognized as exploitable phenomena useful in creating novel processes and products in space.

In 1966, personnel from NASA's Marshall Space Flight Center embarked on a series of visits to manufacturing companies to explore possible industrial interest in space applications. In 1969, NASA initiated its first formal space processing activities under the program title: "Materials Science and Manufacturing in Space." This program was jointly sponsored by the agency's Office of Manned Spaceflight and Office of Aeronautics and Space Technology. To date, in-space MPS research has been pursued on the Apollo, Skylab, and Apollo/Soyuz manned spaceflight programs.

Apollo[7]

An MPS flight experiment program was inaugurated in 1971 when three "demonstration" experiments were performed on the Apollo 14 lunar mission. These simple science demonstrations consisted of heat flow and convection, electrophoretic separation, and composite casting experiments. On Apollo 16 in early 1972, a more ambitious electrophoresis experiment was conducted, and in 1972 Apollo 17 carried a heat-flow and convection demonstration.

Skylab[8]

The 100-ton Skylab space laboratory station, flown 1973-74, offered the first opportunity for extensive experimentation in the microgravity environment of space. A total of 15 MPS experiments and nine science demonstrations were conducted on Skylab. The complement of MPS experiments included: crystal growth, metal composites, eutectics (a combination of two materials that has a lower melting point than either material alone), welding and brazing, fluid effects, and combustion processes.

A materials processing facility (MPF) was an integral part of Skylab and was designed to accommodate all

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[5] N. J. Barter and D. M. Waltz, *Materials Processing in Space: A Weightless Proposition,* AIAA-80-0878, presented at AIAA International Annual Meeting and Technical Display, Baltimore, Md., May 6-11, 1980, pp. 3-4; E. C. McKannan, *Survey of U.S. Materials Processing and Manufacturing in Space Programs,* NASA TM-82427, George C. Marshall Space Flight Center, Alabama, July 1981, p. 1.

[6] J. H. Bredt, "Status of NASA Space-Processing Research," in *Processing and Manufacturing in* Space, proceedings of a symposium held at Frascati, Italy, by European Space Research Organization, Mar, 25-27, 1974., p. 76; Op. Cit., L.K. Zoner, 1981, pp. 19-20.

[7] J. H. Bredt, op. cit., 1974, p. 77.

[8] *Skylab, Our First Space Station,* Leland F. Belew (cd.), NASA SP-400, Washington, D.C. 1977, pp. 148-1 51; *Skylab Experiments, Materials Science, Vol. 3,* NASA EP-1 12, May 1973; *Proceedings of Third Space Processing Symposium—Skylab Results, vol.* 1 and 2, Alabama, June 1974.

Skylab space processing experiments involving the melting and resolidification of materials. This facility was capable of venting into space, thus providing an evacuated environment for the experiments desired. A multipurpose electric furnace, capable of reaching 1,000° C, was fitted within MPF allowing eight metals experiments to be conducted.

Apollo/Soyuz[9]

The joint Soviet-American Apollo/Soyuz Test Project (ASTP), which flew in 1975, carried 12 space processing experiments and three demonstrations. Among them: crystal growth of semiconductors, zero-gravity processing of magnets, surface tension-induced convection, density separation during solidification of two alloys, and halide eutectic growth, In addition, two electrophoresis experiments were conducted on ASTP, one of which was developed and funded by the Federal Republic of Germany.

A modified Skylab furnace, capable of reaching 1,150°C with increased control of temperature ranges, was carried aboard the ASTP. ASTP allowed several investigators to confirm Skylab results and make additional tests of previously observed phenomena.

The Apollo, Skylab, and ASTP experiments were conceptually simple and limited in scope. The hardware was designed on the basis of equipment used on the ground and the experiments were supported by limited Earth-based research. Consequently, the experiments were basically reproductions of current techniques of processing materials carried out under low gravity conditions. With the close of the Apollo program in 1975, no further MPS spaceflight opportunities were available.

The STAMPS Report

A special study to provide guidance for NASA's program for materials processing space was published in 1978 by the Committee on Scientific and Technological Aspects of Materials Processing in Space (STAMPS),[10] an ad hoc committee of the Space Applications Board under the National Academy of Sciences (NAS). Drawing on comments and advice from more than 100 experts in materials science and technology, the NAS study concluded that the prospects for economical space manufacturing are limited and need to be better defined on a case-by-case basis. Further, the STAMPS report stated that no examples of economically justifiable processes for producing materials in space could be found.

The STAMPS committee stressed two points that emerged from the testimony of its advisors and from previous materials experimentation in space:[11]

> First, the space environment usually contributes at least as many problems as it solves. In sophistication, reliability, convenience, and cost, terrestrial experimentation is generally superior to what can be expected in space. Second, space experimentation will have little value unless its planning is founded on substantial Earth-based information and unless the results are coupled to those of complementary terrestrial programs. "

The STAMPS report indicated that some space environment parameters, such as the level of vacuum, temperature, or high-energy radiation can be better realized on Earth. Even long periods of low gravity, achieved only through orbital flight, may be jeopardized by several factors. Among these are: gas venting, fluid dumps, use of evaporators, crew motions, and perturbations of the shuttle orbit itself. These factors could induce accelerations, creating small forces of gravity (G-jitter), which in turn might affect the low-gravity requirement of space processing.

Singled out in the report were commercial space processing of vaccines using electrophoresis (the separation of particles of different mass/charge ratios in an electric field) and growing silicon crystals for use in electronics. The STAMPS study found no clearcut advantage in either case over terrestrial processes, In the case of electrophoresis, use of the technique on Earth has not yet been optimized.

The study group commented that low gravity appears to offer certain capabilities in studying the properties of boiling, combustion and melting, processes that are not now well understood. It was also felt that the ability of containerless processing to avoid contamination and increase purity may hold great promise. But even these possibilities must be subject to critical evaluation of comparative costs and likelihood of success. The NAS study group indicated that the commercial utilization of such understanding lacks promise.

The STAMPS committee suggested that the organization and management of future space processing should include the use of the space shuttle as a national facility. This would include use of the Spacelab by scientists and engineers working in universities, government laboratories, or industrial concerns. User rates should be established, but not designed to cover the total real cost of operating the facility.

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[9] *Apollo-Soyuz Pamphlet No, 8: Zero-G Technology,* NASA EP-140, Washington, D.C. October 1977.

[10] *Materials Processing in Space,* report of the Committee on Scientific and Technological Aspects of Materials Processing Space, National Academy of Sciences, Washington, D. C,. 1978.

[11] Ibid.

In concluding its findings, the STAMPS study suggested the demonstration and development of significant materials processing in space techniques should be paid for by NASA. To this end, the committee suggested certain technical and management changes to improve the effectiveness of the NASA MPS effort. The STAMPS report noted that NASA's MPS efforts had "suffered from poorly conceived and designed experiments, often done in crude apparatus, from which weak conclusions were drawn and, in some cases, overpublicized."

In consonance with the recommendations of the STAMPS committee, a scientific advisory committee has been formed, responsive to the MPS Division Director, to aid in future program planning and policymaking relative to scientific aspects of the program. Peer groups have been empaneled to assist in the selection and periodic review of scientific experimentation and the periodic review of plans and policies.[12]

Terrestrial Facilities

In the absence of spaceflight opportunities for MPS experiment, NASA began using drop tubes and drop towers, aircraft, and sounding rockets to simulate the microgravity environmental J Using such ground-based research technologies, prospective MPS investigators could acquire microgravity test data to: 1) establish experiment parameters, 2) establish proof of concept, and 3) provide specimens for laboratory research.

Drop tubes and towers

To provide a low-cost, flexible and readily available low-g test facility, the Marshall Space Flight Center operates two drop tubes (one of 100-ft length and one of 300-ft length). These drop tubes provide 2 to 4 seconds of microgravity.

In drop tubes, molten droplets are released into a column of vacuum and are solidified during 2.6 seconds of vertical free fall, thus experiencing an effective force of 10-7 g. Typical experiments utilizing this facility include studies in high-temperature calorimetry, and in liquid densities, surface tensions, and volume changes due to solidification,

In using the drop tower, an experiment package is placed in a canister thrusted by small rocket motors to overcome air resistance and guide-rail friction. Experiment-laden canisters as heavy as 204 kg can experience an effective force of as little as 10^{-5}g during a 4-second drop tower test. Drop towers proved invaluable in verifying apparatus and experimental concepts flown on Skylab. Typical experiments are similar to those performed in a drop tube.

Research aircraft

NASA employs KC-1 35 and F-1046 aircraft, flying on parabolic trajectories, to provide 10 to 60 seconds of microgravity. Experiment packages flown in the KC-1 35, because of the size of the aircraft, can be larger in size than in the small F-104B, although approximately twice the microgravity environment can be obtained (30 to 60 seconds) by the jet fighter. Minimum gravity level obtainable is approximately 10-2 g. However, this value is unsteady, and therefore these means are unsuitable for precise experiments. Although the data obtained from research aircraft are limited, such flights do allow for valuable crew training, experiment hardware development, and verification tests.

Sounding rockets

The space-processing application rocket (SPAR) program has been instituted to provide some continuity in flight experimentation between the ASTP flight and the space shuttle MPS opportunities.[14] The SPAR rocket is a Black Brant sounding rocket equipped with recoverable payload system. SPAR was introduced in 1975 and has accomplished nine flights to date. Typically, SPAR can attain between 4 to 7 minutes of low-gravity phenomena, providing levels of 10^{-5} to 10^{-6}g for payloads up to 300 kg. Because of the severe launch environment as measured by acceleration, vibration and spin rate of SPAR at liftoff, and later spin down, MPS experiment design is an arduous undertaking. The short flight times of SPAR are not conducive to crystal growth or biological separation. However, they can be used for certain fluid and solidification experiments. The SPAR program has led to an inventory of low-cost hardware, suitable for longer duration experimentation during shuttle operation. A materials experiment assembly (MEA) designed to be compatible with the shuttle/Spacelab has been developed by using SPAR technology.

Shuttle/Spacelab Programs

An operational space shuttle will further the evolution of materials processing in space. MPS experimentation on planned shuttle flights of up to 1 month will make use of the following shuttle facilities:[15]

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[12] E. C. McKannan, op. cit., July 1981, p. 18.

[13] Materials Processing in Space Program: Handbook for Participants, Prepared for NASA by ORI, Inc., February 1980, pp. III-5 to III-19.

[14] J. H. Bredt, "NASA Plans for Space Processing Experiments on Sounding Rockets," in *Processing and Manufacturing in Space,* proceedings of a symposium held at Frascati, Italy, Mar. 25-27, 1974, pp. 71-73; R. j. Naumann and H. W. Herring, op. cit., 1980, pp. 99-103.

[15] E. C. McKannan, op. cit., July 1981, P. 41.

Small Self-Contained Payloads

These containers are available for rent by companies, universities, and private citizens for a cost dependent upon the size and weight of the experiment package. Containers with a maximum weight of 200 lb and measuring 5 ft^3 can be rented for $10,000 (in 1975 dollars). They are accommodated on a space-available basis and must contain their own power and internal data recording systems. Though limited by size and the absence of in-space manipulation, the small self-contained payloads may provide data useful in larger Spacelab experimentation or in joint endeavors between industry and NASA.

Materials Experiment Assembly

The first article of new materials processing hardware to be flown in the shuttle is the MEA, a self-contained package attached to a Spacelab pallet. MEA has been developed to be compatible with SPAR technology and reconditioned SPAR equipment. MEA operates under its own power, containing a control computer, heat rejection system, and data recorders, and can accommodate up to four experiments in its separately sealed subenclosures. It is anticipated that private institutions may wish to lease MEA from NASA to conduct experiments of a proprietary nature, although legal and financial aspects of this possibility have yet to be clarified.[16]

Spacelab Modules and Pallets

Shuttle MPS systems can be divided into two groups: 1) those located in the pressurized Spacelab module, and 2) those positioned on the Spacelab pallet. ' Spacelab is a habitable module providing a shirt-sleeve laboratory for scientists and engineers to work in space. Carried into orbit in the shuttle cargo bay, Spacelab remains attached to the orbiter for flight durations of up to 1 month. The interior of the module is fitted with racks arranged in single and double assemblies to house experiments.

Unpressurized, u-shapted segmented pallets can also be attached in the orbiter cargo bay. These pallets form an open porch, exposing instruments directly to space and accommodating experiments controlled from Spacelab, the orbiter flight deck, or the Earth. Up to five pallets can be fitted in the cargo bay and combinations of moducles and pallets can be flown.

The major "facility-class, multiuser instruments" presently under development in the shuttle/MPS program consist of:[18]

- *Fluid Experiment System (FES):* Mounted in a double rack aboard Spacelab, the FES experiment uses Schlieren photography and holography to study fluid behavior under microgravity.
- *Vapor Crystal Growth (VCG) System:* Crystals are to be grown from fluids, vapors, or from melts of solid materials, recorded by holographic and video recording in common use with the FES.
- *Acoustic Contain Containerless Positioning Module (ACPM):* The ACPM is located on a pallet and uses 3-axis acoustic positioning to control the position and rotation of a sample heated radiantly to temperatures up to 1,600° C.
- *Solidification Experiment System (SES):* A modular furnace facility "that can accommodate up to 16 samples per flight that are automatically loaded and unloaded on command. These samples can be processed with uniform heating and cooling or with a temperature gradient and directionally solidified. SES is to be located on a Spacelab pallet.

As funding permits, additional MPS/shuttle activity is expected to include the following systems:[19]

- *Floating Zone System:* Used to determine how far the zone refining technique can be carried in space, and to what degree crystal size and purity can be increased. Attached to a pallet.
- *Electromagnetic Containerless Processing System:* A processing module for heating and cooling control independent of positioning control. Attached to a pallet.
- *Bioseparation System:* Designed to enhance understanding of electrophoresis and its variations. Contained in Spacelab.
- *Electrostatic Contain Processing System:* Used for processing and shaping larger, complex materials. Contained in Spacelab.

Future MPS Efforts

Three types of materials processing experiments have been selected for future shuttle missions. These are:

Group 1. Experiments that take advantage of the greatly reduced convective flow to provide quiescent growth or solidification conditions with precise control of temperature, growth rate and composition. Experiments in this category include:

- growth of solid-solution single crystals;
- semiconductor materials growth in low-g environment;

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[16] OP, cit note 17, pp. III-52-III-53.

[17] J. R. Carruthers and L. K. Zoner, "Materials Processing Studies in Space, " NASA (unnumbered) Apr. 10, 1979, pp. 20-23.

[18] N. J. Barter and D, M. Waltz, op. cit., May 1980, PP. 4-5.

[19] D. Dooling, "The Space Factory" in the *Illustrated Encyclopedia of Space Technology,* pp. 21 9-220; R. J. Naumann, "U.S. National Report on Materials Processing in Space, " presentation to Working Group 8, Materials Science in Space, COSPAR meeting (No. 78-1 15), Innsbruck, Austria, June 1978, pp. 20-22.

- vapor growth of alloy-type semiconductor crystals;
- HgI_2 crystal growth for nuclear detectors;
- solution growth of crystals in zero gravity; and
- alined magnetic composites.

Group 2. Experiments involving glasses or glass processes. These experiments take advantage of the containerless aspects of space processing as well as the absence of Stokes bubble rise to investigate phenomena that cannot be unambiguously studied on Earth. Experiments in this category include:

- refining of glasses in space;
- physical phenomena in containerless glass processing; and
- containerless preparation of advanced optical glasses.

Group 3. The remaining experiments depend primarily on the absence of sedimentation to keep a material of different density in suspension during a process. Experiments in this category include:

- solid electrolytes containing dispersed particles;
- liquid miscibility gap materials; and
- production of large particle size monodisperse latexes in microgravity.

It is anticipated that the projected needs of MPS, as measured by numbers of samples, processing time, and power required to support sustained, systematic MPS activity, will surpass present shuttle capabilities. Use of a 2S-kW power system has been advocated to extend shuttle stay-time in orbit (from a maximum 30 days to 90 days) and to provide greater levels of power supportive of MPS payloads. Longer duration shuttle flights, coupled with increased power to conduct experiments, would reduce the net cost of experimentation.

Eventually, a materials experiment carrier (MEC) could serve as a transition between exploratory MPS research and prepilot manufacturing plants. MEC would carry several second-generation MPS modules and, attached to the 25-kW power system, would contain its own heat-rejection equipment, control and data systems. As a total unit, MEC and power system would fly freely, utilizing the shuttle only to deliver raw materials and to extract finished products for return to Earth, [20]

It is conceivable that the MEC activity will require increased human attention, necessitating habitable, Spacelab-type modules, which could lead to a manned space station. This station may well serve as a national space facility for large-scale, commercial space processing.[21]

Conclusions

The scientific basis for manufacturing commercial products in space is limited, resting on a total of 8 hours of in-space research. The economic rationale for fabricating materials in space, therefore, can be assessed only when a suitable reservoir of knowledge has been established. The result from sounding rockets, aircraft, and ground facilities as well as from the limited experimentation aboard spacecraft suggest, however, that space processing techniques which yield products of high value and low volume may be commercially feasible.

It must be recognized that even if a material is identified that is sufficiently unique, useful, and valuable to be manufactured or processed in space, the high inherent cost of space processing will be a strong incentive for industry to find means of duplicating the process on the ground or to find a cheaper substitute for the material. For this reason it may be desirable for the Government to subsidize the initial phases of MPS research and product development. The continued and orderly development of space-based manufacturing techniques will depend heavily upon the establishment of a firm national commitment to maintain and enhance U.S. space capabilities.

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[20] R. J. Naumann and H. W. Herring, op. cit., 1980, pp. 107-108.

[21] D. M. Waltz and R. L. Hammel, "Space Factories, " (77-56), presented to the 28th International Astronautical Federation (IAF), Prague, Sept. 25-Oct. 1, 1977.

Appendix E

World Climate, the Oceans, and Early Indications of Climatic Change

Definition. -''Climate" is how one characterizes the weather at a particular place as it occurs over periods of weeks, years, centuries, or millenia. The modern notion of climate includes its variation and extreme occurrences as well as its average conditions.

At the present time, there is accuracy in the detailed 3-to 5-day weather forecasts. For periods longer than that, one begins to speak in less detailed terms, to describe more general features such as mean conditions and the likelihood of various departures from the mean. Over these longer periods of time (weeks, months, seasons), the climate at a particular place seems to be influenced by progressively more distant forces, such as ocean conditions, solar radiation, and polar ice variations. Thus, we speak of an interactive climate system which includes atmospheric, oceanic, cryospheric and solar influences among other factors.

Historical Perspective

Recent dramatic advances in meteorology and climatology are due to three concurrent streams of development. First, the basic scientific understanding of atmospheric (and oceanic) behavior has grown. Physical and mathematical models have been constructed which duplicate rather well the overall behavior of the atmosphere. Detailed numerical models as used in weather forecasts show reasonable predictive skill. Climate models, though much less precise in time and space resolution, successfully duplicate the large features of the observed climate. Second, and more recently, electronic computers have enabled the development of more detailed and complex models and the solution of their associated mathematical equations. The large computing machines also enable the inclusion and effective treatment of vast amounts of actual data rather than summarized data or proxy parameters.

Third, and most recent, observations from space provide truly global data to describe global-scale climate. A pair of polar-orbiting satellites can view each point on Earth four times a day. A satellite in geosynchronous orbit can continuously monitor conditions over almost a whole hemisphere.

These advances led to the Global Atmosphere Research Program (CARP) conducted during the last decade. The objective of this program was to observe the atmosphere and produce the most comprehensive set of data ever compiled. These data were then to be used to increase understanding of the behavior of the atmosphere, to improve models, and to assess our ability to predict future behavior of the atmosphere. A second major objective was to improve our understanding of the Earth's climate.

The data from the Global Weather Experiment (GWE)–the ultimate phase of GARP–are **still being** analyzed, but already dramatic results are coming to light. For instance, through a combination of surface drifting buoys and satellite-borne data collection systems, measurements taken during the **GWE revealed a previously unobserved complexity in the atmospheric conditions over the Southern oceans.** These vast, remote areas had been largely unmonitored prior to the GWE. In addition, satellite-acquired cloud image data have revealed important interhemispheric flows which influence atmospheric conditions in the Northern Hemisphere. These findings are important because the large-scale aspects of climate are truly global in nature. This has become progressively clear over the years, as scientists such as Hadley, Rossby, Walker, Bjerknes, and many others, have described the overall features of the planetary atmospheric flow about the Earth. Now means are becoming available that demonstrate directly, through observations, the global nature of climate.

Over the last decade, we have become increasingly aware of our vulnerability to extreme climate events. The "Dust Bowl" conditions of the 1930's and their attendant impacts on agriculture and the economy have been well documented. During 1972, unanticipated drought and adverse growing conditions led to severe shortages in the world-wide sup**ply** of grains. This led to adverse domestic economic impacts including the U.S. sale of wheat to the Soviet Union at prices lower than the world prices. The effect of the 1973 Middle East oil embargo was heightened when fuel shortages occurred while there was very cold weather in New England and the Midwest. The California drought of 1976 and 1977 would have had very adverse effects had it persisted any longer.

Because modern society is vulnerable to climate occurrences, important benefits could also result from knowing climate variations in advance. jack Thomson, a noted meteorologist, has estimated that the total annual monetary loss due to poor weather conditions was approximately $13 billion (in 1971). Of that amount, about $418 million could have been saved if reliable **30-** and 90-day forecasts had been available. The larger part of the "protectable" loss required **shorter forecasts, 5 days or less. Thompson found the sectors most benefiting from climate forecasts to be: agriculture,** energy, public safety, construction, communications, and electric power. Given the large increase in energy costs since 1972, the potential savings from reliable climate forecasts should today be much greater than estimated by Thompson.

Just as the value of reliable climate forecasts is being defined, the research community is developing promising techniques for providing reliable seasonal forecasts as much as 6 months in advance. These results have come from diagnostic studies of the "Southern Oscillation." This phenomenon involves a family of climate fluctuations around the globe—including links between atmosphere and ocean conditions in the tropical Pacific and subsequent climate behavior over North America. Warming of central equatorial Pacific water typically leads to displacement of the North American jet stream northward over the West and southward over the East. This causes below normal surface temperatures in the populous eastern United States and warm temperature in the West. The severe winter of 1976-77 (following the 1976 El Nino ocean warming) was typical of this pattern.

The hope for seasonal forecasts lies in the recognition that ocean conditions oflen persist for several months. Thus, when appropriate ocean conditions develop (usually during our spring and summer) they will indicate the likelihood of subsequent anomalous winter conditions occurring in the United States.

In a more recent study, Brown-Weiss confirmed that 3-to 4-month forecasts would be very useful to public utilities for planning natural gas purchases and in planning the mix of petroleum products (e.g., the relative amounts of gasoline versus heating oil).

In addition to forecasts, there are many important uses of climate information falling under the general heading "Applied Climatology." This refers to the statistical characterization of the climate based on the data record. Examples are: the estimation of fuel and electric power demand based upon heating and cooling degree days; planting crops based on the latest data of a killing frost; designing dams based on maximum probable precipitation. Many of these statistical application techniques have been developed because reliable forecasts have not been possible. others, for instance those associated with the design of structures, would probably continue even if forecasts were available because the life of the structure is so long.

Finally, there are important applications which require "current climate" information. For example, in monitoring growing conditions in areas important to worldwide commodity trading, it is important to analyze current conditions in relation to the climate norm. Crop yield models require not only the current weather data but also the climatology for the regions. To be useful, these data must be gathered, processed and disseminated to users very quickly.

Mindful of our vulnerability to climate, our opportunities to improve our knowledge of climate, and the opportunities to make beneficial use of improved climate information, the Congress passed and the President enacted the National Climate Program Act (Public Law 95-367, dated Sept. 17, 1978).

The National Climate Program

The purpose of the National Climate Program is "to understand and respond to natural and man-induced climate processes. " In establishing the national program, the act set up mechanisms for coordinating and integrating the climate activities of the Federal agencies. In particular, the act established a National Climate Program Office as lead entity for administering the program and required the preparation of a 5-year plan to state the goals and priorities of the program and the roles of the Federal agencies in conducting the program.

The current (and first) 5-year plan emphasizes the production of useful climate information based on existing knowledge while simultaneously expanding our understanding of climate and its impact on society. The priority programs (and associated lead agencies) in each of these activity areas are as follows:

Activity category	*Principal thrust*	*Lead agency*
1. **Providing climate products**	**Generation and dissemination of climate information**	**NOAA**
	Climate prediction	**NOAA**
II. Responding to impacts and policy implications of climate	**Carbon dioxide, environment, and society**	**DOE**
	Climate and world food production	**USDA**
III. Understanding climate	**Solar and Earth radiation**	**NASA**
	Ocean heat transport and storage	**NSF**

Potential Contributions From Space Capabilities

Direct satellite measurements and satellite relay of data will make important contributions to all of the above tasks. Considering the continuing elements of the National Climate Program, space contributions and requirements on space systems are likely to be as follows:

Impact Assessment: Effects *of climate on processes and natural resources.* —This area of the program concerns direct climate effects such as the development of crop yield models and energy demand models in terms of climate variables. Demonstration programs such as the Large Area Crop Inventory Experiment (LACIE), and the snowmelt runoff project in California have provided important tests of the uses of space-acquired data. It is recommended that such activities continue with even greater end-user involvement. These demonstration projects provide for development of effective user application models.

Climate System Research: *a) Developrnent of climate simulation and prediction* models.—The main contribution to this area is likely to be from improved computer power and computation techniques. Space systems will provide better global data both as input to the models and as a check on model outputs. This will remove input data as a source for model errors and permit selection of the best modeling approaches.

b) Studies of physical climate processes.–In order progressively to extend our knowledge of the overall climate system, certain key processes are selected for detailed study. There is, for instance, a good deal of interest currently in ocean-heat transport, air-sea interactions, the oceans' role in the global carbon cycle, and stratospheric processes. Space systems, in conjunction with other measurement techniques, will contribute significantly to these process studies.

Data, Information, and Services: ***a)*** *Observation.*– The object here is to compile an accurate, objective record of climate behavior for both applications and research. It is in **this area that space capabilities will make the most important contributions** to climate activities. The observation programs are subdivided along climate regimes: atmosphere, oceans, cryosphere, stratosphere, and solar. The contributions are likely to be as follows:

1) ***Atmosphere:*** Data from the operational weather satellites are first used for weather purposes. These data are then archived and become a major contribution to the climate record. They include atmospheric temperature, moisture, cloud imagery, and sea-surface temperature.

2) ***Oceans:*** As the oceans cover three-fourths of the Earth's surface, they have a profound effect on the climate. Because the areas are so vast, satellites, in combination with in situ devices, provide an effective approach to measurements. Plans are now being formulated for progams extending into the next decade to understand the oceans' role in climate. **A** key aspect is how the oceans store, transport, and redistribute heat globally. These problems will be addressed through a progressive series of studies culminating in a global ocean circulation experiment. A typical interim experiment is the CAGE experiment to measure the fluxes of heat, mass, and momentum through "fixed" ocean and atmospheric boundaries. Satellites will be needed to give the heat balance at the top of the atmosphere and provide other supporting data (e.g., data collected from drifting buoys).

A key satellite experiment in ocean climate studies will be the TOPEX mission. As currently planned, the mission will use a satellite altimeter and radar scatterometer to measure sea-surface topography and wind fields. The aim is to provide information on surface currents and wind stress, The mission may include a microwave radiometer to provide improved sea-surface temperature data. These data, especially on a global scale, are very important to the understanding of the transport of energy from lower to higher latitudes and the exchange of energy between the ocean and the atmosphere. The TOPEX mission derives from the GOES, SEASAT family of altimetric satellites. It is planned for flight in the mid- 1980's.

3) Cryosphere; The expansion and recession of the polar ice packs are thought to be important indicators of climate. The annual variations in the extent of continental snow packs may also be an indicator. Certainly the extent of continental and polar ice cover influences the radiation balance of the planet. The ICES satellite mission is an experiment to give detailed data on the great Greenland and Antarctic ice packs.

One recent study indicates that the rise in sea level since 1940 may be related to the melting of the polar ice caps as a result of atmospheric warming due to increased CO_2in the atmosphere. The melted ice would tend to cool the oceans and thereby the atmosphere, masking a direct thermal signal of increased CO_2. Satellite data on the oceans, polar regions and the stratosphere will be needed to gain conclusive data on these questions.

4) ***Stratosphere:*** Important progress has been made in developing satellite-borne stratospheric composition measurement techniques. Much of this effort has been stimulated by concern over changes in the stratospheric ozone layer. An ozone monitoring sensor is being developed for incorporation onto the operational weather satellite system to enable ozone monitoring.

At the present time, the precision in satellite ozone measurements is about that of Earth-based measurements. But satellite data provide a global view difficult (if not impossible) to infer from the sparse ground measurement network.

5) ***Solar:*** The Sun provides the energy which gives rise to atmospheric and oceanic movements. **There are attempts under way to measure variations** in solar **energy arriving at and leaving the Earth (the radiation budget) and to relate** such variations to climate variability. The Earth radiation budget experiment is part of this effort. Because of the complex nature of atmospheric absorption, it is necessary to monitor the radiation above the atmosphere. Spacecraft provide the only means for continuous solar and Earth radiation monitoring.

6) ***Diagnosis and Projection:*** Climate diagnosis is the detailed analytical and statistical study of climatic events to try to relate climate observations (temperature, pressure, winds, etc.) with the inner workings of the climate system. Diagnostic studies associated with the Southern Oscillation (SO) and other atmospheric and oceanic phenomena hold potential for developing new techniques for seasonal climate prediction.

Because ocean conditions tend to persist over several months, it may be possible to predict several months in advance when certain abnormally cold winters are likely to occur over the populous eastern United States.

However, in order to verify these hypotheses and assess the reliability of resulting predictions, much better sea-surface temperature (SST) data will be needed. The most reliable data are probably provided by ocean buoys. But these data leave wide ocean areas uncovered. Reliable satellite-acquired data, because of wide area coverage, will be a great improvement. Existing satellite-measured SST data are not sufficiently precise to meet climate requirements; improved SST sensors are required.

Requirements From the National Climate Program

Now that the program components have been introduced, it is of interest to discuss certain requirements inherent to climate monitoring. The overriding requirement is for a continuous, intercomparable data record for a span of time that is climatologically significant. In most instances, this is several years. More generally, the longer the record the more valuable it is in determining the likelihood of "extreme" occurrences. Yet, even a period of few years exceeds the life of most satellite sensors. Thus, in the planning for monitoring from space, account must be taken of the need for continuity of data, requiring intercalibration of instruments, documentation of data handling techniques, and so forth. This is referred to as the development of climatically significant data sets.

Secondly, because of the nature of the climate system and the resulting central tendencies of the data, monitoring for climate is likely to require greater precision than short-term monitoring (e.g., weather). That is, where one is measuring diurnal variations in temperature there are likely to be greater fluctuations than, say, in the annual mean temperature from year to year.

Thirdly, there must be a commitment to acquire and prepare new and existing data for climate uses. This may involve some risk. At this stage, one is not always certain that the "best" parameters are being measured. Nevertheless, in order to make useful tests, analyzable data sets covering significant time periods must be available, For example, it was planned that the Earth radiation budget should be monitored over at least one solar activity cycle (1 1 years). Yet, because of severe budget constraints, there is no activity under way to sustain the measurements beyond the initial system to be launched in 1984.

Because of the vast and remote areas involved, and because of the general hostility of the environment for measurement equipment, satellite systems (in conjunction with in-situ platforms) offer a reliable, cost-effective way to collect important ocean-climate data. This was demonstrated during the global weather experiment. During this and the next decade, efforts must be made to gain further knowledge of the processes by which the oceans transport and store heat. New satellite techniques (for measuring surface currents, wind stress, and surface temperature, interalia) have promise for playing major roles in those efforts. Stratospheric monitoring and polar ice monitoring will also contribute to early detection of climate change.

The Climate Program Impact Upon National Space Policy

OTA has outlined six principles and associated issues underlying U.S. civil space activities. The impact of the National Climate Program is analyzed in relation to each of these principles quoted below:

> 1. "Space activities maybe justified by political, as well as by social, economic, scientific, technological, or other benefits."

In the early years of the space program, national space goals were primarily engineering-oriented. The cutting edge of space technology was in learning how to successfully launch and recover space vehicles, to "put a man on the Moon by 1970." Now that much of the engineering capability is secured, it would appear that any new national space goals are more likely to be oriented toward application of space technology. Indeed, the national governmental policy challenge for the 1980's seems to be shaping up to be to make the economy stronger, in which case all programs, including space activities, will be evaluated in terms of their economic contribution.

The long-term goals of the national climate program are primarily economic—to be able to routinely predict climatic variations (weekly to seasonal) for economic payoffs in energy conservation, agricultural productivity, water resources management, and resort management as well as long-term climatic change potentially associated with, say, atmospheric CO_2 buildup. The near-term objectives of the climate programs are primarily in research aimed at improved understanding of climate on which to build climate prediction skills. Therefore, the climate program applications of space technology can be seen as economic in the long run and mainly research or scientific in the short term.

There are certain characteristics of the climate program's space requirements that must be taken into account in the formulation of any comprehensive national space policy:

a) Remote sensing from space is essential to climate research and forecasting, For obtaining certain climatic parameters, e.g., measuring the Earth radiation budget, there are no alternatives to spaceborne sensors.

b) Climate studies require long periods (often measurable in decades) of data continuity. This is different from most other space applications (e.g., weather). Consequently, the accuracy and precision of data useful for short-term purposes may be wholly inadequate for climate.

c) Climate studies require truly global coverage. Present coverage is inadequate because data from the tropical oceans and the Southern Hemisphere, which are crucial to climate forecasts, are most sparse. Future coverage may be even less complete if the number of meteorological satellites is reduced in response to fiscal constraints.

d) Overall, **U.S.** climate program activities are more reliant upon multipurpose satellites, especially meteorological satellites, than on climate satellites. There is an open question whether this trend will be continued into the future because climate research requirements and the evolving climate forecasting skill will necessitate:

—monitoring climate-unique parameters potentially requiring unique satellite orbits or unique sensors;

—improved long-term data continuity; and

—increased data volume, possibly demanding the total payload of a given satellite.

On the other hand, if these capabilities can be obtained through reliance upon multipurpose satellites, it would seem potentially more efficient. A system of multipurpose Earth remote-sensing satellites could result in fewer space platforms carrying the same same sensing capacity.

> 2. "The United States should be 'a leader' (cf. Space Act of 1958) in 'aeronautical and space science and technology and in the application thereof to the conduct of peaceful activities . . . "

Climate research and climate forecasting are inherently global, Climate activities, following the precedent set in meteorology, are characterized by a high degree of international cooperation and sharing, e.g., GARP. However, in practice most of the remote sensing in support of climate studies around the world has been done by U.S. satellites.

While the U.S. commitment to climate studies and forecasting will serve to maintain **U.S.** visibility in world climate activities, the objectives of U.S. climate activities are primarily economic and scientific. It is in the best interest of the **U.S.** climate program to maintain an atmosphere of international cooperation and participation so as to gain scientific and engineering support from other nations in the interests of efficient and rapid cooperative progress in climatology.

> 3. "Civilian and military space activities will be conducted in separate (and independent) institutional structures. "

Since the climate program will, for the foreseeable future, procure much data from space platforms justified primarily for other purposes, ownership of those platforms whether by military or civilian institutions will make no difference so long as data quality, quantity, and timeliness are adequate. Conversely, if the climate program requirements evolve in such a way as to necessitate dedicated climate satellites, the integration of **U.S.** military and civilian satellite systems under a common institutional structure could affect climate data acquisition, but that effect cannot now be projected.

> 4. "The National Aeronautics and Space Administration, established by the Space Act of 1958, is authorized to conduct research, development, construction, testing, and operation for research purposes of (aeronautical and) space vehicles. It is not authorized to have operational responsibility for space systems. "

The national climate program, as a user of multipurpose satellites owned and operated by nonclimate program entities, would be neutral on the question of the identity of the U.S. civil space system operator. However, to the degree that the climate program's data requirements necessitate a dedicated climate satellite system, the operational responsibility question will be acute.

5. "Commercialization of space technology and applications should be promoted. "

From the point of view of the potential commercial supplier of climate remote-sensing data, the climate program with its requirement for long-term data continuity would appear a promising market.

From the point of view of Government climate program managers, commercialization of the satellites that supply climate observations is of concern primarily in terms of cost but also in terms of data quality and timeliness. If a large, diversified (many firms) satellite remote-sensing industry were to develop, inter-firm competition could be expected to work in the interests of the climate programs to keep data prices low and data quality, quantity and timeliness high. If, on the other hand, the private remote sensing industry were to be essentially monopolistic, the climate program managers' concerns would be justified.

On a broader commercialization question, if the entire climate program were to be commercialized, it seems obvious that the satellites supplying the climate data would also be commercial. Commercialization of the entire climate program is a possibility only in the long run after climate forecasting has been proven, and even then total commercialization seems improbable.

The evidence is strong that the core of the climate program will remain a public function for the foreseeable future and that no more than the value-added components will be commercialized. Climate forecasts, the long-term objective of the climate program, are certain to be, in part, public goods. Certain major public policy decisions, such as those potentially associated with CO_1, acid rain, or ozone, will be heavily dependent upon climate forecasts. The forecasts themselves and the capability to produce them will almost certainly be a government responsibility because the market for such global climate predictions will not be commercially viable. Hence, a core climate program capability will be governmental for the foreseeable future.

6. "The United States will engage in cooperative, international activities involving peaceful uses of outer space. "

As discussed under issue B, climatology is global in nature, U.S. climate activities are rooted in international cooperation, and remotely sensed climate data are openly shared in the international community. Nonetheless, it is an open question whether the U.S. would feel comfortable being reliant upon foreign owned/operated satelites for our core climate observations.

Appendix F

THE INTERNATIONAL LEGAL REGIME OF OUTER SPACE

Introduction

Few **human endeavors have occasioned the degree of international legal scrutiny given to the development of space technology. Because space activities generally involve technologies that do not respect national boundaries, new stresses have been placed on traditional international legal principles.** These principles, based on the rights and powers of territorial sovereignty, are often in conflict with the most efficient utilization of new space systems. In order to resolve the complex legal problems that have arisen in the space age, nations, both technologically advanced and developing, have been forced to rely increasingly on international cooperation.

The purpose of this appendix is to discuss the important legal principles and international organizations that have been developed to regulate the use of outer space. Additionally, it describes the possible effects that these principles and organizations may have on private sector interest and investment in specific space systems. It should be noted that since this discussion focuses exclusively on the international legal regime of outer space, the many complex issues involved in the domestic regulation of private investment in space technology are not discussed.

International Organizations

This appendix only discusses the activities of the Committee on the Peaceful Uses of Outer Space (COPUOS), the International Telecommunication Union (ITU), and the United Nations Education, Scien**tific and Cultural Organization** (UNESCO). Though there are numerous other international organizations whose activites involve outer space to some degree, most are not involved in formulating of international law and policy.

Committee on the Peaceful Uses of Outer Space

COPUOS has been, and continues to be, the chief architect of the international legal regime of outer space. COPUOS was established by resolution of the General Assembly of the United Nations (U. N.) in 1958 to study the problems brought into existence by the advent of the space age,[1] COPUOS is composed of two subcommittees, one of which studies the scientific and technical, and the other the legal aspects of space activities. Since its inception, the Legal Subcommittee has been responsible for the formulation of five major treaties:

- Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, Including the Moon and Other Celestial Bodies (1 967)[2]
- Agreement on the Rescue of Astronauts, the Return of Astronauts and the Return of Objects Launched into Outer Space (1968)[3]
- Convention on International Liability for Damage Caused by Space Objects (1 972)[4]
- Convention on Registration of Objects Launched into Outer Space (1 974)[5]
- Agreement Governing the Activities of States on the Moon and Other-Celestial Bodies (1979)6

With the exception of the 1979 Moon agreement, the United States has signed and ratified each of these international agreements.

COPOUS is currently conducting negotiations in the following areas:

- *Remote sensing.* COPUOS has been negotiating a statement of principles on remote sensing since 1979. Considerable disagreement still exists between states on this subject and it is unlikely that a consensus will be reached in the near future.
- Direct *broadcast satellites.* COPUOS has been involved in trying to reach agreement on a set of principles for direct broadcast satellites since 1968. However, there seems to be no easy solution to the debate betweeen states advocating

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[1] U.N. **General Assembly Resolution 1348** (XIII) **"Questlon of the Peaceful Use of Outer Space, " Dec. 13, 1958.**

[2] 18 UST **2410; TIAS 6347; Senate Report No. 8, 90th Cong. 1 st sess., April 17, 1967; Senate Committee on Aeronautical and Space Sciences, 90th Cong., 1st sess., staff report on "Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, " committee print, 1967.**

[3] 19 UST **7570; TIAS 6599; "Agreement on the Rescue of Astronauts, the Return of Astronauts, and the Return of Objects Launched into Space: Analysis and Background Data;" Senate Committee on Aeronautics and Space Science, 90th Cong. 2d sess., committee print, July 16, 1968.**

[4] **24 UST 2389; TIAS 7762; Senate Committee on Aeronautics and Space Sciences, 92d Cong., 2d sess., staff report on "Convention on International Liability for Damage Caused by Space Objects, " committee print, 1972.**

[5] TIAS 8480; Senate **Committee on Aeronautical and Space Sciences; 94th Cong., 1st sess., staff report on "Conventlon on Registration of Objects Launched into Outer Space, " committee print, 1975.**

[6] U. **N. General Assembly Resolution A/34/68, Dec. 14, 1979; Senate Committee on Commerce, Science, and Technology, 96th Cong., 2d sess., "Agreement Governing the Activities of States on the Moon and Other Celestial Bodies, " committee print, 1980**

free flow of information and those advocating a regime of prior consent.

- *Nuclear power sources in space.* Since the Cosmos 954 accident in 1978, in which radioactive debris from a Soviet satellite fell on northern Canada, there has been increased international concern over use of nuclear energy to power satellites. COPUOS has focused its attention on four major issues: safety, prior notification, emergency assistance, and liability for damages. To date, no international consensus has been reached.
- *Delimitation of outer space.* The question of where air space ends and outer space begins has troubled international legal theorists since the beginning of the space age. The Soviets have recently proposed that outer space should be considered to begin in the area of 100 to 110 km above sea level, The United States has consistently maintained that no decision should be taken until a more complete understanding of the scientific and technical characteristics of low-orbit satellites is obtained.
- *Military activities in space.* COPUOS has periodically addressed issues relating to militarization; current treaties ban nuclear weapons and other weapons of “mass destruction. ” Discussions of military activities have increased lately, now that both the United States and the Soviet Union are developing anti-satellite devices and other weapons. A number of developing countries have objected to militarization, and in 1981 the Soviet Union proposed that the General Assembly discuss a draft treaty prohibiting the stationing of all weapons in outer space, with special reference to the U.S. space shuttle. The U.S. has objected to attempts by COPUOS to take up this issue.

International Telecommunication Union

ITU is an international, intergovernmental organization and the U.N.S’ specialized agency for telecommunications.[7] The purpose of ITU is to coordinate and regulate international activities in the field of communications. Since radio communication is essential to all outer space activities, it was logical that ITU be charged with the task of allocating radiofrequencies for space as well as terrestrial communications. To this end, a World Administrative Radio Conference (WARC) was held in 1959 that resulted in the first international agreements applicable to space activities.

The basic governing documents of ITU are its Constitution and its Administrative Regulations. The Constitution is revised by the Plenipotentiary Conference when technological (and recently, political) changes reduce the effectiveness of existing provisions. The Administrative Regulations are updated more frequently through WARCS and Regional Administrative Radio Conferences (RARCS) and are the means by which the technical coordination and regulation of international communications is actually accomplished. Membership is open to all countries and currently ITU has 154 members. The formal results of RARCS and WARCS are reached by each country exercising one vote and, when ratified by the member states, they have the force of international treaties.[8]

The primary function of ITU is to allocate the radiofrequency spectrum among competing services (e.g., fixed, mobile, aeronautical, maritime, and space) and to register the frequency assignments of its member states in order to avoid interference. The International Frequency Registration Board (IFRB) of ITU performs many of these important technical functions. IFRB records the frequency assignments made by different countries in accordance with WARC and RARC regulations and furnishes advice to ITU members on technical matters (e.g., the maximim practicable number of radio channels in those portions of the spectrum where harmful interference may occur). In 1973, the duties of ITU were enlarged by a modification of its Convention. This modification provided that IFRB was “to effect . . . an orderly recording of the positions assigned by countries to geostationary satellites. ”[9]

ITU has been the major forum in the recent debates regarding the a priori grant of portions of the radio spectrum and the geostationary orbit to countries presently lacking space technology. This subject is discussed in greater detail in section IV.

UNESCO

Though UNESCO does not have a technical or regulatory role such as ITU nor a broad mandate similar to that of COPUOS to address international space issues, it has been active in the discussion of space-related problems. Some of its more important activities include:

- ***Convention on satellite signal piracy.*** UNESCO, together with the World Intellectual Property Organization, sponsored an international conference in 1974 which adopted the “Convention Relating to the Distribution of Programme-Carrying Signals Transmitted by Satellite”.[10] States party

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[7] For a detailed look at ITU, see, *Radiofrequency Use and Management: Impacts From the World Administrative Radio Conference of 1979,* Office of Technology Assessment, 1982.

[8] International Telecommunications Convention (Geneva), Dec. 21, 1959; TIAS 4892, 12 UST 1761.

[9] International Telecommunication Convention, 1973, article 10(3); TIAS 8572.

[10] N.M. Matte, *Aerospace Law,* 1977, *pp.* 39-40.

to the Convention agree to "take adequate measures" to prevent the distribution of "program e-carrying signals" by unauthorized personnel.

- *Satellite broadcasting and the free flow of information.* UNESCO has also been working on a "Declaration of Guiding Principles on the Use of Satellite Broadcasting for the Free Flow of Information, the Spread of Education and Greater Cultural Exchange".[11] Strong objections have been voiced against this declaration on the grounds that instead of encouraging the free-flow of information, it encourages censorship. Many believe that this Declaration of Principles was used by its authors as a means to attract international attention to the "New World Information Order" (discussed infra, sec. III (c)(3)).
- *Technical assistance to member states.* UNESCO has worked with a number of African, Asian, and Latin American states, helping them to assess their general communication needs. UNESCO is presently conducting several long-range studies to determine the practicality of using regional satellite systems to supply educational and cultural development programs to certain developing countries.

The Status of Nongovernmental Entities

As the role of private industry varies within each of the nations of the world, and as it is those nations and not their private industries that enter into international space agreements, it is understandable that some confusion exists as to the legal status of private industry in outer space. This section will examine some of the practical and theoretical problems that arise when trying to fit the activities of private enterprise into a framework designed primarily to regulate the actions of states.

In the United States, it has been consistent government policy to encourage the involvement of private enterprise in its space programs. When President Eisenhower announced his administration's space policy in 1960, he stated:

> (T)o achieve the early establishment of a communication satellite system which can be used *on a commercial basis* is a national objective which will require the concerted capabilities and funds of both Government and *private enterprise* . . . With regard to communication satellites, I have directed the National Aeronautics and Space Administration to take the lead within the Executive Branch both to advance the needed research and development and to *encourage private enterprise* to apply its resources toward the earliest practical utilization of space technology *for commercial civil communications requirements* (emphasis added).

This enthusiasm for private enterprise was not shared by all nations. In 1962, the Soviet Union submitted to COPUOS a "Draft Declaration of the Basic Principles Governing the Activities of States Pertaining to the Exploration and Use of Outer Space." It was suggested in the draft that, "All activities of any kind pertaining to the exploration of outer space shall be carried out solely and exclusively by States . . ."[13] The United States responded to this position by pointing out that pursuant to U.S. policy, as reflected in the Communications Satellite Act of 1962, private firms had already been given the right to engage in space activity. In order to reconcile this conflict, the United States proposed that states bear the responsibility for the launching of space vehicles, whether such vehicles be the property of the state or its nationals.[14] In this manner, the United States hoped to reassure other states that private activity could be controlled, albeit indirectly, through international regulation.

The principle of state responsibility for the actions of its nationals is incorporated in both articles VI and IX of the 1967 Outer Space Treaty.[15] Although the 1967 Principles Treaty does not specifically grant private industry the right to undertake activities in outer space, the U.N. debates on this subject make it clear that such activities were contemplated by the drafters.

A few authors have suggested that though the 1967 Principles Treaty may sanction the *presence* of nongovernmental entities in space, article I can be read to prevent the *commercial use* of outer space.[16] Article I states, in relevant part:

> The exploration and use of outer space, including the Moon and other celestial bodies, shall be carried out for the benefit and in the interests of all countries, irrespective of their degree of economic or scientific development, and shall be the province of all mankind.

It is argued that commercial use would be contradictory to article 1, in that its drafters intended the benefits of outer space exploration and use to flow *to* all mankind, and not to private investors. This somewhat technical argument finds little support in either the specific language of the 1967 Outer Space Treaty or its legislative history.

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[11] U.N. Document A/AC, 105/1 04, July 25,1972.

[12] White House Press Release, Dec. 30, 1960; see also, D.D.Smith, *Communication via Satellite*, 1976, p. 72.

[13] U.N. Document A/AC. 105/L.2; U. N. Document A/5/81 Annex 3.

[14] U.N. Document A/AC.105/L.5 U, N. Document A/5/81, Annex 3.

[15] See Article VI of the Outer Space Treaty.

[16] See, for example, Marcuff, *Traite' de Droit International Public de l'Espace*, 1973, p. 671.

State Responsibility for Nongovernment Entities

Given that private enterprise may conduct activities in space for profit if the appropriate state will take responsibility for such actions, it becomes necessary to examine the nature of this responsibility. Some authors, in analyzing article **VI** of the 1967 Principles Treaty, have suggested that a state’s responsibilities are extensive:

> (While no one would doubt the need for government control over space activity at its present stage, the second sentence of article VI would prohibit, as a matter of treaty obligation, strictly private, unregulated activity in space or on celestial bodies even at a time when such private activity becomes most commonplace. Although the terms “authorization” and “continuing supervision” are open to different interpretations, it would appear that Article VI requires a certain minimum of licensing and enforced adherence to government-imposed regulations.’[17]

In addition to article Vi’s general statement of responsibility, article IX of the Principles Treaty requires that if a state or its nationals are going to undertake any activity in space which “would cause potentially harmful interference with activities of other states,” then the state planning the activity “shall undertake appropriate international consultation before proceeding with any such activity.”[18] Article IX’S requirement that the international consultation shall precede the proposed activity is quite significant, in that it imposes an active duty to regulate rather than a merely passive duty to supervise. Under article IX a state has a duty to interfere with or prohibit altogether potentially harmful activities by its nationals at least until such time as the effects of the proposed activity are made known to the international community.

The Outer Space Treaty does not attempt to direct states as to how these responsibilities should be carried out. This is appropriate since a state’s control over its nationals involves complex questions of domestic law. The 1967 Outer Space Treaty, on the other hand, was not written to supply an exhaustive set of rules to regulate the conduct of states, but rather to sketch the rough outline of a new international regime.

One of the more important attempts to delineate the responsibilities of states in outer space occurred in 1972 with the adoption by COPUOS of the “Convention on International Liability for Damage Caused by Space Objects.” This treaty extends the concept of state *responsibility* to include the concept of *liability* for damage caused by space objects. Article II of the Liability Treaty establishes the principle that a launching state is absolutely liable for “damage caused by **its** space object on the surface of the Earth or to aircraft in flight.”[19]

Two points should be mentioned here. First, the 1972 Liability Convention does not grant either rights or responsibilities to nongovernmental entities. If the nationals of a launching state cause damage, it is the state damaged, under article VIII, which “may present to a launching state a claim for compensation.”[20] This somewhat formalistic approach to compensation is sufficient at this time since states exercise almost complete control over launch and tracking facilities and there is no “pure” private enterprise in outer space. However, as the activities of private enterprise increase in frequency and scope, new and more efficient procedures will have to be developed to handle the claims for compensation which are certain to arise.

A second point of interest concerning the Liability Convention is the fact that it applies, by its terms, only to “launching states” which are defined in article I as:

- a state that launches or procures the launching of a space object; and
- a state from whose territory or facility a space object is launched.

Under this scheme, if state A launches a space object for the nationals of state B, both states are considered launching states and have joint liability for damage under article V of the Liability Convention. This is the case even though under the language of article IX of the 1967 Principles Treaty it is state B that bears the international responsibility for the “potentially harmful” activities of its nationals. This problem is somewhat alleviated by article V of the Liability Convention that allows a state that has paid compensation for damages “to present a claim for indemnification to other participants in the joint launching.”

These rather complex international remedies are presently workable only because it is the activity of states and not individuals that predominates in space. **As** this situation changes a new legal regime, which more fully comprehends the role of the individual in space activities, will have to be developed.

Limitations on Nongovernmental Entities

Having discussed the status of private activity in space and the methods of control over such activity, it is important now to examine the limitations that the present legal regime of outer space places on the activities of the private sector. To answer this question requires an analysis of several recently articulated principles. These are the Principle of Nonappropriation

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[17] Jasentuleyana and Lee, *Manual* of Space *Law,* vol. 1, 1979, p. 17.

[18] See Article IX of the Outer Space Treaty.

[19] See Article II of the Outer Space Treaty.

[20] See Article VIII of the Outer Space Treaty.

of Space Resources, the Principle of the Common Heritage of Mankind (CHM), and the New World Information Order.

PRINCIPLE OF NONAPPROPRIATION

The 1963 Declaration of Legal Principles included the statement that, "Outer space and celestial bodies are not subject to national appropriation by claim of sovereignty, by means of use or occupation, or by any other means. "[21] With minor changes, this language is repeated in article **II of the 1967** Outer Space Treaty and article XI (2) of the proposed Moon Treaty. The legislative history of these instruments and the subsequent activities of states has revealed little controversy concerning the prohibition against appropriation by claim of sovereignty. However, this harmony of opinion has not recently been shared with regard to the prohibition against appropriation by means of use or occupation.

The issue of appropriation by "use and occupation" involves a number of complex considerations. Most ventures into space involve some degree of appropriation, since the placement of a satellite into orbit precludes the use by other states of that same orbit, Any alteration of the present "first come, first served" use of the geostationary orbit or in the rights of priority now recognized as applying to currently operating systems could have serious repercussions on the U.S. communications industry. Some third world countries have suggested that radiofrequency assignments and the incidental use of the geostationary orbit should be limited to the life of the satellite. This suggestion is contrary to the current practice in the United States. In the United States, **the** Federal Communications Commission licenses communication common carriers to provide a continuous service to the public. Some third world countries have argued that this method of continuous use is tantamount to an appropriation. As a result they advocate the a priori allocation of radiofrequencies and orbit positions (see sec. **IV** infra).

The proposed Moon Treaty recognizes the problems inherent in a "first come, first served" method of allocating resources and attempts to limit the effects of de facto appropriation on the exploration and exploitation of the Moon and other celestial bodies.[22] The recognition of the problem appears in article VIII where it is stated that states parties "shall not interfere with the activities of other states parties, " This section clearly grants an important right to "first users" of Moon resources. This right is then qualified by article IX'S statement that a "station shall use only that area which is required for the needs of the station" and article XI (3)'s statement that such stations "shall not create a right of ownership over the surface or subsurface of the Moon or any areas thereof. "

THE COMMON HERITAGE OF MANKIND (CHM)

Though the CHM principle is complex in its application, in theory it is quite simple. Basically stated, the principle maintains that there are certain resources, such as the minerals on the ocean floor and on the Moon, that are presently under the jurisdiction and control of no sovereign power. These resources, being finite and exhaustible, should not be allocated to the developed countries on a first come, first served basis, but rather, should be used for the benefit of all nations. Though this principle has recently received its greatest attention in relation to the Law of the Sea Convention, it has frequently appeared in discussions concerning the exploration and use of outer space.[23]

In 1958, when President Eisenhower announced his administration's space policy, he called upon states "to promote the peaceful use of space and to utilize the new knowledge obtained from space science and technology for the benefit of mankind."[24] Subsequent to this statement, the concept that space activities should be undertaken for the benefit of mankind appeared in the NAS Act of 1958,[25] in important General Assembly resolutions on space and as article I of the 1967 Principles Treaty. Although these "common interest" clauses found their way into the major space treaties, there was considerable uncertainty as to their status within the body of international law. Some authors have suggested that these "common interest" clauses were merely pragmatic principles without legal force. Others believe that the placement of the "common interest" clauses within the operational part of treaties, as opposed to a mere statement of intentions in the preamble, indicated that such provisions must be regarded as binding.[26] **As a** binding principle it

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[21] U.N. General Assembly Resolution 1962, article XVIII, par. 3.

[22] U.N. General Assembly Resolution 34/68, "Agreement Governing the Activities of States on the Moon and Other Celestial Bodies, " Dec. 14, 1979.

[23] R. B, Owens, statement at hearings on the Moon Treaty, "Agreement Governing the Activities of States on the Moon and Other Celestial Bodies, " before the Subcommittee on Science, Technology, and Space of the Senate Committee on Commerce, Science, and Transportation, 96th Cong., 2d sess., 1980. Ambassador M C. W. Pinto of Sri Lanka has Interpreted the CHM principle to apply to the law of the sea in this manner: "This (Common Heritage of Mankind) means that those (seabed) minerals cannot be freely mined. They are not there, so to speak, for the taking. The common heritage of mankind is the common property of mankind. . If you touch the nodules at the bottom of the sea, you touch my property. If you take them away, you take away my property. "

[24] "Introduction to Outer Space," an explanatory statement by the President's Science Advisory Committee, 1958, p. 1.

[25] C. Q. Christol, "The Legal Common Heritage of Mankind: Capturing an Illusive Concept and Applying it to World Needs, " XVIII the *Colloquium on the Law of Outer Space, 1976,* p. 42.

[26] N. M. Matte, "Aerospace Law: Telecommunications Satellites, " Center for Research of Air and Space Law, McGill University, p. 38.

created an obligation among states “to be in some form responsive to the interest of developing countries, and to provide for some form of distribution of benefits derived from such (space) activities.”[27]

The principle of CHM has generally been opposed by the private sector. The most common argument heard in this regard is that any attempt at international regulation of the profits derived from space will inhibit private enterprise from making the necessary investments in space technology. Advocates of this position often point to article XI **(7)** of the proposed Moon Treaty’s statement that one of the purposes of the international regime is to assure “an equitable sharing” of resources.[28] It is **argued that the concept of equitable sharing is inconsistent with the concept of profit, and** in the absence of the profit motive private enterprise cannot be expected to risk capital on space investments.

The most repeated criticism of the CHM principle is that it lacks proper definition. It is argued that its “novelty, generality, philosophical underpinnings—as opposed to legal—and uncertain historical pedigree” render it far too vague to act as a tool in the regulation of international conduct.[29] These criticisms are valid at least to the extent that they regard the principle’s uncertainty, for except for article XI of the Moon Treaty’s suggestion of an international regime, nowhere are a state’s duties under the CHM principle defined.

THE NEW WORLD INFORMATION ORDER

The New World Information Order is a principle espoused by the Soviet Union and certain third world countries that maintains that there is an imbalance in both the amount and kind of news emanating from the information and communication systems controlled by the Western industrialized nations. These countries allege that as a result of this imbalance the third world and communist countries have been portrayed in a distorted manner to the populations of the developed countries, while the populations of the developing countries have been subjected to the “cultural imperialism” of a capitalist, consumer-oriented society. The New World Information Order seeks to remedy this situation by: 1) encouraging the development of a third world information infrastructure; 2) controlling the West’s access to developing countries; and 3) limiting the Western media’s ability to disseminate information in developing countries. so

The long-term effects of this principle on the free flow of information throughout the world are, for the most part, beyond the scope of this report. However, the continued adherence to the New World information Order by a substantial number of Communist and third world countries could have important near-term effects in the field of satellite communications. Most notably, the Western developed nations can expect to encounter strong opposition to the previously used “first come, first served” method of allocating the electromagnetic spectrum and the orbital positions in the geostationary arc (discussed in greater detail below). In addition, private communications firms may encounter new tariffs and regulations designed to slow the flow of information and communications services to the third world. New tax laws have also been proposed which would require the payment of a portion of the assessed value of information flowing into or through a country. Future restrictions can also be expected on the establishment of ground stations and on access to the foreign transmission lines necessary for the terrestrial transmission of satellite data.

Communications Satellites

Not long after ITU began to regulate satellite communications certain international tensions arose concerning its methods of allocating what many believed to be scarce space resources.Jl Radiofrequencies that have been duly registered with ITU receive international recognition and protection. Therefore, early registration of a radiofrequency is given priority over later requests for the registration of the same frequency. Many developing nations have voiced opposition to this principle of priority on the basis that future access to the radio spectrum and positions in geostationary orbit, which are necessary for effective satellite communication, will be limited by the present activities of the developed nations.

Reflecting this concern, the ITU convention was modified in 1973 to state:

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[27] Ibid., p. 39.

[28] Article XI (7) of the Moon Treaty states: “7. The main purposes of the international regime to be established shall include:

(a) The orderly and safe development of the natural resources of the Moon;
(b) The rational management of those resources;
(c) The expansion of opportunities in the use of those resources;
(d) An equitable sharing by all States Parties in the benefits derived from those resources, whereby the interests and needs of the developing countires as well as the efforts of those countries which have contributed either directly or indirectly to the exploration of the Moon shall be given special consideration.

[29] C. Q. Christol, “The Common Heritage of Mankind in the Moon Treaty,” paper submitted to symposium on “Space Activities and Implications, ” Center for Research of Air and Space Law, McGill University, Oct. 16-17, 1980.

[30] B. Cowlan, “internationally Organizing for Space, ” paper submitted to International Conference on Doing Business in Space, Nov. 12-14, 1981, reprinted in *ALI-ABA Conference Materials.*

[31] N.M. Matte, op. cit.

> **In** using frequency bands for space radio services, Members shall bear in mind that radio frequencies and the geostationary satellite orbit are limited natural resources, that they must be used efficiently and economically so that countries may have equitable access to both **in conformity with the provisions of the Radio Regulations according to their needs and the technical facilities at their disposal .32**

There is considerable confusion in the international community as to what is meant by the "efficient and economical" use of radiofrequencies and the geostationary orbit. The developing states have argued that because these resources are limited, an a priori allocation should be made to assure that countries which presently do not utilize space may be able to do so in the future. The states with substantial space resources have generally taken the position that attempts to reduce space to an "international condominium" are neither efficient and economical nor sanctioned by international law.

It has been argued by the United States that the allocation of space resources on any basis other than use is inefficient because it reduces the incentive to adopt spectrum and orbit conserving technologies and patterns of use.[33] The United States and other developed countries maintain that through the creative use of the frequency spectrum, as seen in the adoption of 30/20 G Hz for communications, and the development of new space systems, such as large space platforms, the future needs of the developing countries can be easily met. However, some third world countries feel that it is not in their best interest to continue to rely on the developed countries to supply their communication needs. Several of these countries, notably India and Brazil, are in the process of developing an indigenous satellite communication capability. In the near future, the communication systems developed by these countries will be less sophisticated and therefore less efficient than those designed by nations already well versed in space technology. A priori allocation plans are attractive because the satellites they will be developing may require the type of orbital spacing presently utilized. The developing countries may argue that it is in their best interest to resist an international regime predicated on the development of advanced, resource-efficient technology because such a regime would render their indigenous technology obsolete.

There is some question as to whether a priori allocation plans might not be contrary to the letter and the spirit of the 1967 Outer Space Treaty. Article 2 of the treaty states:

> **Outer space, including the Moon and other celestial bodies, is not subject to national appropriation by claim of sovereignty, by means of use or occupation, or by any other means.**

The developed countries have taken the position that the assignment of orbital positions to states would constitute an appropriation and therefore is forbidden by the Outer Space Treaty. The third world has generally argued that since the geostationary orbit is only useful in connection with communication satellites, and since ITU regulates the latter, it should also have jurisdiction over the former. The United States has opposed this extension of the power of ITU.

The subject of a priori allocation of radiofrequencies and geostationary orbit positions was addressed but not resolved at the latest WARC in 1979. This subject will be debated again at the 1983 RARC and the 1984 WARC where, it is hoped, a reasoned and practical solution can be found that will accommodate the needs of both the developing and the developed nations.

Direct Broadcast Satellites (DBS)

DBS are a new generation of communications satellites capable of transmitting signals strong enough to be picked up by individuals utilizing small (less than 1 m in diameter), home receiving dishes.J[4] This is to be contrasted with the currently operating communications satellites that transmit weak signals to large, fixed Earth stations that must then rebroadcast the signal to the public using terrestrial facilities.

The major advantage of DBS technology is that it does away with the need for an elaborate terrestrial distribution system, thereby making possible the transmission of programs to widely dispersed populations, remote areas, or to countries without a sophisticated communications infrastructure. The research and development necessary to realize DBS technology was undertaken by the National Aeronautics and Space Administration and proven in both the U.S. ATS-6 and the Canadian/U. S. CTS satellites. Presently, France, Germany, Luxembourg, and groupings of Arab and Scandinavian countries are planning for DBS systems or for multipurpose communications satellites able to directly broadcast.Js Some of these systems are planned for operational status by the mid-] 980's.

Though DBS technology offers the potential for large-scale educational, health and public service programing–a fact that was amply proven by the

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J~Internat(ona/ Telecommunication Convention, op.cit

[33] Office of Technology Assessment, Op. cit., P. 30

Wee generally: "Policies for Regulation of Direct Broadcast Satellites," Federal Communication Commission staff report, September 1980.

JSBarbara Luxenberg, "Preliminary OK for Direct Broadcast Satellites, " Aeronautics and Astronautics, September 1981, p. 20.

U.S./India ATS-6 experiments–some have raised serious questions concerning the international regulation of this technology. The Soviet Union has expressed concern that DBS maybe used to spread propaganda or misinformation designed to create social unrest. Several third world countries have expressed the fear that this technology will be used by the Western, developed nations as a tool of cultural or economic imperialism. It is feared that commercial advertising by the developed countries might disrupt the social fabric of developing nations by creating a demand for consumer goods that is not consonant with national plans for social and economic development.

The Soviet Union, France, and numerous Third World countries have argued that the sovereign rights of a country prohibit broadcasting across national boundaries in the absence of a prior agreement with the receiving state. The United States has opposed this view and has advocated a policy of free flow of information. The opposition of the United States to the doctrine of prior consent has centered around four major themes that can be summarized as follows:qb

1. *There has been insufficient experience with broadcast satellites to determine what, if any, political constraints should be placed on their use.* In the DBS debates of the early 1970's the United States argued that it was unwise to fashion regulations without knowing the specific problems that would be caused by this technology. The ATS-6 experiments in India were frequently used as an example of the fact that the control over programing and distribution of DBS services could remain firmly within the local government of the receiving country, thereby obviating the need for international regulation. The United States still maintains that as experience with transborder DBS service grows, the fears of "cultural imperialism" presently harbored by many nations will diminish.
2. *Enactment of a set of political principles for DBS could inhibit the development of technology valuable to the third world countries.* Most of the technical problems with DBS have been, or are in the process of being solved. **The two major questions from a domestic U.S. perspective are how to configure DBS satellites to respond to specific markets and whether DBS offers a significant economic advantage over conventional means of broadcasting. Restrictive international regulations may make economically unjustifiable** the expenditures necessary to adapt DBS technology to the particular needs of developing countries. This is particularly true if the private sector is to play a significant role in this development.
3. *ITU regulations constitute a sufficient safeguard against unauthorized DBS transmissions.* Some U.S. experts argue that the need for technical coordination has obviated the need for political regulation. In addition to providing working definitions for the various types of DBS service and allocating frequencies to DBS, the ITU, in 1971, adopted Radio Regulation 428 A which provides:

   > **In devising the characteristics of a space station in the broadcasting-satellite service, all technical means available shall be used to reduce, to the maximum extent practicable, the radiation over the territory of other countries unless an agreement has been previously reached with such countries.**

   In the view of the United States, the ITU procedures are a sufficient safeguard against the misuse of DBS technology and are, in fact, a form of prior consent. The countries that do not accept this position argue that the ITU decisions deal only with the physical transmission of a satellite signal and do not address the right of countries to regulate the message content of foreign broadcasts.
4. *The prior consent principle undermines the concept of international free flow of information.* The United States has taken the position that the free exchange of ideas and information, as affirmed in article 19 of the Universal Declaration of Human Rights and other U.N. resolutions, should not be inhibited.q[7]Many U.S. experts believe that acquiescence in a prior consent regime for DBS would be an undesirable precedent that could be applied to other means of communication or dissemination of information. The DBS issue can be viewed as one aspect of a growing pattern of restraints being promoted under the umbrella of the New World Information Order.

In addition to the positions held by those advocating prior consent and the United States, a third, compromise position has been put forward in a joint proposal by the Canadian and Swedish Governments.[38] This proposal suggests that advance agreement would be necessary concerning the basic issue of broadcasts by the satellites of one country into the territory of another country. However, the content of the trans-

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[36] **The following four themes derived from: Wilson P. Dizard, "The U.S. Position: DBS and Free Flow,"** *Journal of Communication, vol. 30,* **spring 1980, pp. 157-168.**

[37] U.N. General **Assembly Resolution 217 (III), Dec.** 10,1948.

[38] **"Draft Principles Governing Direct Television Broadcasting by Satellite,"** U.N. **Document A/AC, 105/1 17, 1973.**

missions would be left to the discretion of the broadcasting country. To date, this proposal has not gained substantial support of either the United States or the countries which advocate a prior consent regime.

Remote Sensing

The term remote sensing refers to the use of satellites capable of detecting reflected or emitted electromagnetic radiation for the purpose of gathering information about the Earth .39 Presently, the only civilian remote-sensing system is the Landsat system of the United States. Though this system is operated by the Government, there is considerable indication that the private sector may have a significant role to play in remote sensing in the near future. (For a more complete discussion of the private sector's role in remote sensing, see ch. 2) If the policy decision is made in the United States to encourage the private sector to take as active a role in remote sensing as it has taken in communications satellites, the Government must ensure the existence of a receptive economic and legal environment. The existence of a restrictive international regime could limit the private sector's ability to invest in this new technology.

There has been considerable discussion in the international community concerning what restrictions, if any, should be placed on the use and distribution of remotely sensed data. Some of the major principles being discussed are:

Prior consent. Some states have argued that countries planning to engage in remote-sensing activities should be required first to obtain the permission of the countries they intend to sense.

Restricted data dissemination. A recent joint proposal by the French and the Soviets has suggested that information gathered by remote sensing should not be transferred to third-party states without the prior consent of the state sensed.

Limited resolution. Some states have evinced concern regarding advances in remote-sensing technology that will allow extremely detailed observation. They feel that if such data were freely available from a civilian commercial system it might threaten the security and economic interests of the sensed state.

Unrestricted sensing. The United States has generally opposed the placing of restrictions on remote-sensing activities and data dissemination. The United States presently maintains a policy of free data dissemination and regularly supplies Landsat data to other governments, international organizations, private sector businesses and individuals.

It is helpful to analyze some of the legal arguments used to defend the positions that were articulated above. Basically, arguments that favor limiting remote-sensing activities are premised on the assumption that the rights of territorial sovereignty allow a state to protect itself from information gathering activities directed toward its own natural resources. There is very little in either traditional international law or i n the treaties which deal specifically with space that substantiates this assumption.

It is generally accepted that a sovereign nation may protect itself from information gathering activities within its borders, either on the ground or from the air. The legal basis for each of these manifestations of sovereignty is not necessarily applicable to outer space activities. Because traditional international law recognizes that the laws of a sovereign state apply to all within its borders, activities of foreign nationals may be controlled while they are physically within that state. Likewise, traditional international law, and article 2 of the Chicago Convention of 1944, recognize that a state has absolute sovereignty over the air space above its national boundaries,[40] Control over the activities of foreign nationals in both cases is predicated on the fact that such activities are accomplished within the sovereign territory of a state.

Remote sensing is problematic from a legal perspective because, on the one hand, it is an activity undertaken in space, and the 1967 Outer Space Treaty guarantees that space shall be "free for exploration and use by all States;" yet, on the other hand, the activity is directed toward the observation of territories under the control of separate sovereign states.

For this reason, many nations have argued that some form of international control is necessary to protect the interests of the sensed states and to prevent abuses that may result from the dissemination of remotely sensed data. The United States takes the position that restrictions on remote sensing would result in data being available to only those states having the financial and technical ability to provide their own space and ground systems. Furthermore, even if a country had the technology to fly a remote-sensing system, it would not be inclined to do so if it knew in advance that it would have to undertake the financially prohibitive and scientifically disadvantageous exercise of separating the billions of bits of remotely sensed data along political boundaries.

Jqs ee generally: National Academy **of Sciences,** *Resource Sensing From Outer Space,* 1977; **N. M. Matte, H.** DeSaussure, *Legal Implications of Remote Sensing From Outer Space,* 1976.

[40] 61 **Statistics 1180, 15 U** .N.T. **S. 295.**

OUTER SPACE TREATY

Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, Including the Moon and Other Celestial Bodies

Done at Washington, London, and Moscow January 27, 1967;

Ratification advised by the Senate of the United States of America April 25, 1967; .

Ratified by the President of the United States of *America May 24, 1967;*

Ratification of the United States of America deposited at Washington, London, and Moscow October 10, 1967;

Proclaimed by the President of the United States of America October 10, 1967;

Entered into force October 10,1967.

BY THE PRESIDENT OF THE UNITED STATES OF AMERICA

A PROCLAMATION

WHEREAS the Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, including the Moon and Other Celestial Bodies, was signed at Washington, London, and Moscow on January 27, 1967 in behalf of the United States of America, the United Kingdom of Great Britain and Northern Ireland, and the Union of Soviet Socialist Republics and was signed at one or more of the three capitals in behalf of a number of other States;

WHERE.AS the text of the Treaty, in the English, Russian, French, Spanish, and Chinese languages, as certified by the Department of Stab of the United States of America, is word for word as follows:

ANNEX XIX

Treaty on Principles Gov
in the Exploration and U
the Moon and other Celes

Activities of States
ter Space, including
s.

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Having considered the report of the Outer Space covering its work during 1966 plished by the Legal Sub-Committee duri from 12 July to 4 August and at New York

Noting further the progress achieve among States Members of the United Nati

Reaffirming the importance of intern activities in the peaceful exploration and us and other celestial bodies, and the importa this new area of human endeavour,

1. *Commends* the Treaty on Principle in the Exploration and Use of Outer Sp Celestial Bodies, the text of which is annexe

2. *Requests* the Depositary Governme and ratification at the earliest possible date

3. *Expresses its hope* for the widest p

4. *Requests* the Committee on the Pea

(a) To continue its work on the elab for damages caused by the launching of o ment on assistance to and return of astrona the agenda of the Committee;

(b) To begin at the same time the stu tion of outer space and the utilization of cluding the various implications of space

(c) To report on the progress of its twenty-second session.

Inspired by the great prospects openi man's entry into outer space,

Recognizing the common interest of exploration and use of outer space for pea

Believing that the exploration and use for the benefit of all peoples irrespective scientific development,

Desiring to contribute to broad intern

ittee on the Peaceful Uses of in particular the work accom- fifth session, held at Geneva 12 September to 16 September,

ough subsequent consultations

l co-operation in the field of uter space, including the Moon developing the rule of law in

erning the Activities of States ncluding the Moon and Other he present resolution;

open the Treaty for signature

uses of Outer Space.

n of an agreement on liability into outer space and an agree- d space vehicles, which are on

questions relative to the defini- space and celestial bodies, in- unications;

o the General Assembly at its

ankind in the progress of the purposes,

ter space should be carried on

l co-operation in the scientific

as well as the legal aspects of the exploratio purposes,

Believing that such co-operation will mutual understanding and to the strength States and peoples,

Recalling resolution 1962 (XVIII), enti Governing the Activities of States in the E which was adopted unanimously by the U 13 December 1963,

Recalling resolution 1884 (XVIII), c placing in orbit around the Earth any obje other kinds of weapons of mass destruction celestial bodies, which was adopted unanim Assembly on 17 October 1963,

Taking account of United Nations Ger 3 November 1947, which condemned propa or encourage any threat to the peace, brea and considering that the aforementioned re

Convinced that a Treaty on Principles the Exploration and Use of Outer Space, inc Bodies, will further the purposes and prin Nations,

Have agreed on the following:

Article Z

The exploration and use of outer sp celestial bodies, shall be carried out for th countries, irrespective of their degree of eco shall be the province of all mankind.

Outer space, including the Moon and for exploration and use by all States with basis of equality and in accordance with i free access to all areas of celestial bodies.

There shall be freedom of scientific in the Moon and other celestial bodies, and international co-operation in such investiga

Outer space, including the Moon and to national appropriation by claim of soverei or by any other means.

Article 111

States Parties to the Treaty shall carry use of outer space, including the Moon and with international law, including the Cha interest of maintaining international peace and security and promoting international co-operation and understanding.

Article IV . .

States Parties to the Treaty undertake not to place in orbit around the Earth any objects carrying nuclear weapons or any other kinds of weapons of mass destruction, install such weapons on celestial bodies, or station such weapons in outer space in any other manner.

The Moon and other celestial bodies shall be used by all States Parties to the Treaty exclusively for peaceful purposes. The establishment of military bases, installations and fortifications, the testing of any type of weapons and the conduct of military manoeuvres on celestial bodies shall be forbidden. The use of military personnel for scientific research or for any other peaceful purposes shall not be prohibited. The use of any equipment or facility necessary for peaceful exploration of the Moon and other celestial bodies shall also not be prohibited.

Article V

States Parties to the Treaty shall regard astronauts as envoys of mankind in outer space and shall render to them all possible assistance in the event of accident, distress, or emergency landing on the territory of another State Party or on the high seas. When astronauts make such a landing, they shall be safely and promptly returned to the State of registry of their space vehicle.

In carrying on activities in outer space and on celestial bodies, the astronauts of one State Party shall render all possible assistance to the astronauts of other States Parties.

States Parties to the Treaty shall immediately inform the other States Parties to the Treaty or the Secretary-General of the United Nations of any phenomena they discover in outer space, including the Moon and other celestial bodies, which could constitute a danger to the life or health of astronauts.

Article VI

States Parties to the Treaty shall bear international responsibility for national activities in outer space, including the Moon and other celestial bodies, whether such activities are carried on by governmental agencies or by non-governmental entities, and for assuring that national activities are carried out in conformity with the provisions set forth in the present Treaty. The activities of non-governmental entities in outer space, including the Moon and other celestial bodies, shall require authorization and continuing supervision by the appropriate State Party to the Treaty. When activities are carried on in outer space, including the Moon and other celestial bodies, by an international organization, responsibility for compliance with this Treaty shall be borne both by the international organization and by the States Parties to the Treaty participating in such organization.

Article VII

Each State Party to the Treaty that launches or procures the launching of an object into outer space, including the Moon and other celestial bodies, and each State Party from whose territory or facility an object is launched, is internationally liable for damage to another State Party to the Treaty or to its natural or juridical persons by such object or its component parts on the Earth, in air space or in outer space, including the Moon and other celestial bodies.

Article VIII

A State Party to the Treaty on whose registry an object launched into outer space is carried shall retain jurisdiction and control over such object, and over any personnel thereof, while in outer space or on a celestial body. Ownership of objects launched into outer space, including objects landed or constructed on a celestial body, and of their component parts, is not affected by their presence in outer space or on a celestial body or by their return to the Earth. Such objects or component parts found beyond the limits of the State Party to the Treaty on whose registry they are carried shall be returned to that State Party, which shall, upon request, furnish identifying data prior to their return.

Article IX

In the exploration and use of outer space, including the Moon and other celestial bodies, States Parties to the Treaty shall be guided by the principle of co-operation and mutual assistance and shall conduct all their activities in outer space, including the Moon and other celestial bodies, with due regard to the corresponding interests of all other States Parties to the Treaty. States Parties to the Treaty shall pursue studies of outer space, including the Moon and other celestial bodies, and conduct exploration of them so as to avoid their harmful contamination and also adverse changes in the environment of the Earth resulting from the introduction of extraterrestrial matter and, where necessary, shall adopt appropriate measures for this purpose. If a State Party to the Treaty has reason to believe that an activity or experiment planned by it or its nationals in outer space, including the Moon and other celestial bodies, would cause potentially harmful interference with activities of other States Parties in the peaceful exploration and use of outer space, including the Moon and other celestial bodies, it shall undertake appropriate international consultations before proceeding with any such activity or experiment. A State Party to the Treaty which has reason to believe that an activity or experiment planned by another State Party in outer space, including the Moon and other celestial bodies, would cause potentially harmful interference with activities in the peaceful exploration and use of outer space, including the Moon and other celestial bodies, may request consultation concerning the activity or experiment.

Article X

In order to promote international co-operation in the exploration and use of outer space, including the Moon and other celestial bodies, in conformity with the purposes of this Treaty, the States Parties to the Treaty shall consider on a basis of equality any requests by other States Parties to the Treaty to be afforded an opportunity to observe the flight of space objects launched by those States.

The nature of such an opportunity for observation and the conditions under which it could be afforded shall be determined by agreement between the States concerned.

.4rtic/2 *XI*

In order to promote international co-operation in the peaceful exploration and use of outer space, States Parties to the Treaty conducting activities in outer space, including the Moon and other celestial bodies, agree to inform the Secretary-General of the United Nations as well as the public and the international scientific community, to the greatest extent feasible and practicable, of the nature, conduct, locations and results of such activities. On receiving the said information, the Secretary-General of the United Nations should be prepared to disseminate it immediately and effectively.

Article Xll

All stations, installations, equipment and space vehicles on the Moon and other celestial bodies shall be open to representatives of other States Parties to the Treaty on a basis of reciprocity. Such representatives shall give reasonable advance notice of a projected visit, in order that appropriate consultations may be held and that maximum precautions may be taken to assure safety and to avoid interference with normal operations in the facility to be visited.

Article X111

The provisions of this Treaty shall apply to the activities of States Parties to the Treaty in the exploration and use of outer space, including the Moon and other celestial bodies, whether such activities are carried on by a single State Party to the Treaty or jointly with other States, including cases where they are carried on within the framework of international intergovernmental organizations.

Any practical questions arising in connexion with activities carried on by international intergovernmental organizations in the exploration and use of outer space, including the Moon and other celestial bodies, shall be resolved by the States Parties to the Treaty either with the appropriate international organization or with one or more States members of that international organization, which are Parties to this Treaty.

.4rticle XIV

1. This Treaty shall be open to all States for signature. Any State which does not sign this Treaty before its entry into force in accordance with paragraph 3 of this article may accede to it at any time.

2. This Treaty shall be subject to ratification by signatory States. Instruments of ratification and instruments of accession shall be deposited with the Governments of the Union of Soviet Socialist Republics, the United Kingdom of Great Britain and Northern Ireland and the United States of America, which are hereby designated the Depositary Governments.

3. This Treaty shall enter into force upon the deposit of instruments of ratification by five Governments including the Governments designated as Depositary Governments under this Treaty.

4. For States whose instruments of ratification or accession are deposited subsequent to the entry into force of this Treaty, it shall enter into force on the date of the deposit of their instruments of ratification or accession.

5. The Depositary Governments shall promptly inform all signatory and acceding States of the date of each signature, the date of deposit of each instrument of ratification of and accession to this Treaty, the date of its entry into force and other notices.

6. This Treaty shall be registered by the Depositary Governments pursuant to Article 102 of the Charter of the United Nations.

Article XV

Any State Party to the Treaty may propose amendments to this Treaty. Amendments shall enter into force for each State Party to the Treaty accepting the amendments upon their acceptance by a majority of the States Parties to the Treaty and thereafter for each remaining State Party to the Treaty on the date of acceptance by it.

Article XV1

Any State Party to the Treaty may give notice of its withdrawal from the Treaty one year after its entry into force by written notification to the Depositary Governments. Such withdrawal shall take effect one year from the date of receipt of this notification.

Article XV11

This Treaty, of which the Chinese, English, French, Russian and Spanish texts are equally authentic, shall be deposited in the archives of the Depositary Governments. Duly certified copies of this Treaty shall be transmitted by the Depositary Governments to the Governments of the signatory and acceding States.

In witness whereof the undersigned, duly authorized, have signed this Treaty.

Done in ...., at the cities of London, Moscow and Washington, the .... day of .... one thousand nine hundred and .... (1).

(1) The Treaty was signed in London, Moscow and Washington on January 27, 1967.

Appendix G

BACKGROUND FOR INTERNATIONAL PROGRAMS

Early United States/Soviet Competition

Prior to world War II, the leading centers of rocket research had been Germany and the Soviet Union. In both cases the primary impetus for research was military, supported by extensive amateur and civilian activities. The United States, by contrast, lacked a coordinated rocket program, though the work of isolated individuals, notably Robert Goddard, helped give the United States an important experimental base.

During the war many nations developed rockets for various military uses, particularly tactical battlefield support (the Soviets relied heavily on massed rocket barrages); but by far the most advanced work was done by the Germans. This culminated, late in the war, in the first long-range unmanned vehicles: the **V-1, an air-breathing "cruise missile" used for short-range attack on population centers such as London, and the much more advanced and dangerous V-2, the first operational ballistic missile.**

At the end of the war two of the rival victors, the United States and Soviet Union, divided up the majority of the German rocket assets. The Soviets, having occupied the main German testing center at Peenemunde on the Baltic Sea, seized the bulk of the hardware, while the Americans (along with the British and French) succeeded in capturing and employing many of the most talented scientists and engineers, including the most important, Wernher von Braun. **In both the United States and U. S. S. R., these resources formed the basis for each country's succeeding rocket** programs.

The direction and pace of these programs were determined above all by the differing military requirements of the two nations. During the decade following World War 11, the United States relied for its security (and that of its allies) on its large fleet of long-range bombers equipped with nuclear weapons. Stationed in Europe and the Far East, these forces were capable of directly attacking the Soviet Union and hence of deterring any hypothetical Soviet conventional attack in Europe. The Soviets, on the other hand, had no comparable delivery system, for they lacked both the bombers and, even more importantly, forward bases within range of the continental United States. The Soviets therefore saw long-range ballistic missiles as the only way to counter U.S. nuclear superiority, and placed a correspondingly high priority on their development. The type of missile they proceeded to build was determined first of all by the extreme heaviness of the first generations of Soviet weapons, as well as by the inaccuracies of the missiles themselves. To be effective at long ranges, even against large unprotected targets (i.e., cities), these missiles had to carry very heavy, high-yield (multi megaton) warheads. Hence, the missiles themselves had to be, above all, large. The result was a series of large, inexpensive, inefficient (relatively low thrust) boosters capable of carrying thousands of pounds halfway around the world —or into orbit. It is these early designs, first perfected in the mid-l 9s0's, that still today serve as the backbone of the Soviet missile fleet, both for intercontinental ballistic missiles (ICBMS) and for orbital launchers.

The United States, in contrast, did not at first feel a similar urgency to develop ICBMS, especially the very heavy variety favored by the Soviets. However, by the mid-l 950's the United States had several rocket development programs under way: the Army's Jupiter booster; the Thor and Atlas missiles (developed by the Air Force); and a civilian booster, Vanguard, which was, however, essentially managed by the Navy.

Contrary to popular belief, the Soviets were not reticent about their intention to launch an artificial satellite; as early as 19.ss, Soviet scientists were predicting success within a few years, and the October 4, 19s7, orbiting of Sputnik was foreshadowed by numerous public statements. Nevertheless, the public and international surprise was intense, and there were widespread demands for the United States to match or surpass the Soviet challenge. There were several reasons. The Soviet Union and United States each had grown accustomed to seeing the other as rivals across a whole range of political, economic, and cultural activities. Both saw themselves as representing social and economic systems whose superiority would be demonstrated by whether they could outperform their competitors. At stake for e,ach was the legitimacy of its system in the eyes not only of its current adherents but of billions of potential adherents throughout the world. The United States was acknowledged to be the leader in economic and scientific affairs, and although the Soviets took pains to publicize the ever-growing amounts of steel, concrete, oil, and foodstuffs produced annually, it was increasingly clear that competition in the nuclear age was more a matter of quality than quantity. In no technical area had the Soviets been able to outperform the West; Sputnik was a blow to the West's confidence in the superior quality of its science and technology, and hence in the superiority of the political/economic system that produced it. With hindsight we can see that Sputnik represented an exceptional case of temporary leadership brought

about by the special emphasis on heavy missiles described above. The sophistication of the Soviet payloads and instrumentation, including their manned capsules, was well below that of even the first U.S. satellites. It did not indicate a comprehensive capability in advanced technologies on a par with the United States; it did not even indicate, as many thought it must, that the Soviets enjoyed a dangerous lead in military ICBMS. The “missile-gap” controversy, which played an important role in the 1960 Presidential election, and which prompted a major commitment by the United States to the deployment of U.S.-based ICBMS and foreign-based MRBMs, as well as to civil defense, was a chimera. There is no doubt that the Soviets, upon seeing Sputnik’s effect on world opinion, did their best to foster the notion of across-the-board Soviet technical and military equivalence, if not superiority, and that this effort, abetted by the extreme secrecy with which the Soviet program was conducted, was largely successful, especially in the third world. In particular, Premier Khrushchev asserted that the Soviets, with their ICBMS, which could supposedly “hit a fly in outer space,” had achieved strategic nuclear parity with the United States.

That these claims were exaggerated became clear in 1962 when Khrushchev, lacking the credible Soviet-based ICBM force he had earlier claimed, attempted to redress the balance by placing MRBMs in Cuba, with disastrous results. Soviet space successes, and the Western reaction, played an important role in public estimates of comparative military strength. The above shows why it was the United States and the U.S.S.R. that were the first to develop boosters capable of launching substantial payloads into orbit. Other countries, lacking these military/competitive needs, did not at first choose to expend the resources needed to develop an independent booster capability. It is instructive to note that France, the European nation historically most eager to have its own launcher, and the one that has already built its own MRBM deterrent, is also Western Europe’s largest nuclear power and the one most determined to remain independent of the superpowers. Similarly, China’s launcher development program has been motivated by its determination to field a nuclear delivery system.

Having developed missiles capable of launching payloads into orbit, both the United States and the U.S.S.R. began to construct a number of different satellites. Scientific instruments, remote-sensing cameras, satellites for weather observation and military surveillance, communications satellites, and manned spacecraft were all flown within a few years of Sputnik. The type and pace of development were determined by a combination of scientific and technical curiosity, **military requirements, prospective social and economic benefit, and, especially for the manned programs, prestige and competition. By the end of the decade, the United States had developed manned and unmanned civilian systems demonstrably superior to those of the Soviet Union. During the 1970’s, competition was reduced,** due partly to d~tente and a general lowering of tensions between the two countries, and also to the differing emphases of the respective programs, While the United States focused on the space shuttle, the Soviets orbited the Salyut series of manned, resupplyable orbiting laboratories. increasingly, competition with the Soviets has changed from open and highly publicized civilian space spectaculars, to secret military and intelligence systems. (For further details see ch. 7.)[1]

Joint European Efforts

In 1960-61, three separate European agencies were created to deal with different aspects of space. The European Launcher Development Organization (ELDO) aimed at creating a jointly funded launcher, eventually named the “Europa. ” ELDO was basically a coordinating body for separate national projects; the eventual plans for Europa called for a British first stage (the Blue Streak military IRBM), a French second stage, a West German third stage, Italian test satellites, Belgian downrange guidance systems, and Dutch telemetry links. By 1968, the cost estimates for the Europa had climbed from an initial $190 million to $71o million to $77o million, causing intense disagreements among the participants. The military implications of possessing a long-range missile complicated agreements even further.[2] As a result of the problems caused by inadequate coordination, none of the 11 test launches of the Europa, the last of which took place in 1971, succeeded in placing a payload in orbit.J Along the way the British, dismayed by rising costs for what they saw as obsolescent technology, decided in 1968 to reduce their financial commitment and eventually withdrew altogether. This left France as the project’s strongest backer. In 1973, the Europa was finally cancelled in favor of a new project, the Frenchdominated Ariane, which was eventually taken up by the European Space Agency (ESA).

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[1] For information on the rivalry between the United States and the Soviet Union, see *Soviet Space Programs 1971-75,* 2 vols., Congressional Research Service Staff Report for Senate Committee on Aeronautical and Space Sciences, Aug. 30, 1976; Jerry Grey, *Enterprise (New* York: William Morrow & Co., 1979); and James Oberg, *Red Star in Orbit, (New* York: Random House, 1981).

[2] Mihiel Schwarz, “European Policies on Space Science and Technology 1960-1978,” *Research Policy 8, 1979,* p. 208.

[3] See *World-Wide Space Activities,* CRS Science Policy Research Division, report done for House Committee on Science and Technology, September 1977, pp. 265-273.

The second major agency was the European Space Research Organization (ESRO) which was formally established in 1962. Loosely modeled on CERN, the cooperative European Nuclear Research Center, ESRO intended to develop satellites and instruments for conducting scientific experiments in space, including tracking and relay stations, and to procure launch services.[4] ESRO (unlike ELDO) achieved a high degree of credibility, and was able to cooperate successfully with NASA and other countries. A major difficulty ESRO faced, one which it shared with ELDO, was the principle of "juste retour" (fair return). Participating countries contributed to the agencies a certain assessment (for ESRO, an amount roughly in proportion to their gross national product), and the agency contracts were supposed to be let in the same ratios; i.e., if France provided 20 percent of the budget, 20 percent of the amount of ESRO'S contracts were supposed to be with French firms (in fact, France's share of the contracts was consistently higher than its budget contribution).s This resulted in many contracts being let on political and partisan grounds rather than to the lowest or most qualified bidder.[6] Eventually, to circumvent the destructive and time-consuming quarreling over contracts, European aerospace and electronics firms formed themselves into three formal multinational consortia-called COSMOS, MESH, and STAR– to bid on European projects.

From 1967 to 1975 (when it merged into the ESA), ESRO launched nine scientific satellites and 168 sounding rockets[7] The most important development over time was a growing interest in applications satellites; in 1968, ESRO was first given a mandate to study applications, especially in communications and meteorology. By 1975, ESRO was engaged in four major applications projects: 1) a maritime navigation satellite, Marots; 2) an experimental communications satellite, OTS; 3) Aerosat, a joint venture with the United States for aeronautical communications; and 4) Meteosat, a regional meteorological satellite.

A third organization, the Conference Europeéne de Telecommunications par Satellites (CETS), was formed to discuss European participation in INTELSAT. It was made up of national Postal, Telephone, and Telegraph (PTT) agencies and played little role in formulating space policy or programs.

In 1966, the members of ELDO, concerned about lack of harmony between countries and programs, established the 12-nation European Space Conference (ESC), which met for the next 9 years and provided the forum for the founding of ESA in 1975.

There was first of alla consensus within the ESC that there should be a single coordinated European program, but there was disagreement about the relative weight to give the three program areas: science, applications, and launch vehicles. Basic science and launcher development were already the province of ESRO and ELDO, respectively, but applications activities were seen as increasingly important. For one thing, U.S. and Soviet successes with communications and weather satellites had shown the usefulness of space applications. For another, there was increased European awareness of the importance of advanced technology in maintaining a competitive position in international trade and influence vis-à-vis the superpowers, especially the United States. In 1967, J. Jacques Servan-Schreiber's book, "The American Challenge, " in which he predicted the decline of European industry faced with American technical and managerial superiority, "polemicized the United States economic invasion of Europe and aroused a popular interest in technology comparable to the Sputnik aftermath in the United States."[8] At the same time, however, there was increasing concern in both Europe and the United States about reaping useful economic and social benefits from space technologies; by the end of the 1960's, there was little enthusiasm on either continent for large prestige projects such as Apollo. To be publicly acceptable, investments had to be justified by concrete and relatively short-term payoffs,

The British skepticism about continuing the Europa project, mentioned previously, reflected this shift; the British saw Europa as an unnecessary and expensive item being pursued to the detriment of more useful and technically advanced applications satellites. The British, along with the Italians and a few others, thought U.S. launchers were perfectly adequate and likely to be considerably cheaper than the inefficient Europa. The prolauncher countries, however, led by France, Belgium, and the Netherlands, thought that the United States could not be counted on to launch European applications satellites that might compete with U.S. systems, especially in telecommunications. The United States had launched ESRO'S scientific satellites without any problems, but there were no guarantees as to other types of payloads.

In 1969, the question of the American relationship became a key issue. In making plans for the post-Apollo space program, U.S. policy makers placed strong emphasis on soliciting European participation,

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[4] 1 bid., p. 237.

‘See Walter McDougall, "Space Age Europe 1957-1 980," paper presented at the Conference on the History of Space Activity, Yale University, Feb. 7 1981, p. 6.

[6] Schwarz, op. cit., p. 211.

[7] *World-Wide Space Activities,* op. cit., pp. 254-256.

[8] Henry Nau, *National Politics and International Technology* (Baltimore: Johns Hopkins University Press, 1974), p. 55.

partly to strengthen political and economic ties and partly to lessen the costs. In October 1969, the United States proposed that Europe undertake to build a major segment of the proposed space transportation system. Emphasis was placed on the "space tug, " an expendable orbit-to-orbit rocket, because the expertise accumulated in developing the Europa could be used to develop the tug. The Europeans concurred, and began extensive planning for eventual construction. However, in 1972 the United States withdrew its offer, partly because the entire post-Apollo program was being scaled back, because of doubts about European technical capabilities; and also because the Air Force thought the military potential of the tug was too great to permit dependence on outside sources.[9] Instead, the United States "offered" the Europeans the sortie lab (later known as Spacelab) or a number of constituent parts of the space shuttle. Withdrawal of the tug proposal angered the Europeans, not only because of the considerable time and expense invested, but because some countries, particularly France, were suspicious that the United States did not want the Europeans to develop their own space transportation capability, and wished instead to retain a U.S. monopoly on launchers. One result was renewed commitment to a European rocket; another was French consultation with the Soviet Union about possible future use of Soviet launchers.

The question of U.S. guarantees to launch European applications satellites was related to U.S.-European collaboration, in that many Europeans were convinced that such guarantees were contingent on European willingness to build and fund part of the U.S. post-Apollo program. In 1971, the United States promised to assist with launches, provided they were "for peaceful purposes and consistent with obligations under relevant international arrangements''.[10] Similar assurances were later granted to all "other countries and international organizations on a nondiscriminatory, reimbursable basis."[11] The United States insisted that this policy would be honored regardless of European participation: the qualification of consistency with "relevant international arrangements" was, however, a potential stumbling block, especially to launching European communications satellites. The relevant agreement was the "International Telecommunications Satellite Organization (INTELSAT) Agreement, " signed August 20, 1971, which, in article XIV, required signatories to consult with INTELSAT to ensure the "technical compatibility" of any proposed operational international telecommunications satellites, as well as to avoid "significant economic harm" caused by regional competition. In fact, this issue did affect plans to launch the French-German Symphonic communications satellite, which the United States agreed to do (in 1971) only after it was declared an experimental rather than an operational system, in part to avoid the issue of whether the United States would launch an operational satellite.[12] This experience strengthened French determination to develop an autonomous launch capability.

Resolution of these issues made the negotiations in ESC over establishing ESA prolonged and complicated.[13] Essentially, the successful outcome involved compromise among the three largest participants, France, Germany, and the United Kingdom, with each agreeing to back the others' preferred projects in exchange for reciprocal support.

The French wanted to build a launcher, specifically the L3S or Ariane, which was first conceived in 1972 as a unilateral French project. In order to get ESA support, the French agreed to provide the bulk of the funding for research and testing (approximately 60 percent), with Germany providing some 20 percent, Belgium 5 percent, and various other participants the remainder. The British reluctantly agreed to a 1 to 2 percent contribution. The Ariane would be launched from France's spaceport at Kourou in French Guiana, and the main contractor would be a French firm, Aerospatiale.

West Germany had been a strong backer of a European launcher and also of the proposed space tug. When the tug offer was withdrawn, the Germans' preferred project became Spacelab, which they saw as a vehicle for conducting scientific and commercial experiments as well as for improving German industrial and technical skills. More so than the French, the Germans believed that U.S. launch guarantees could be trusted. Following high-level talks between President Pompidou of France and Chancellor Brandt of Germany in 1973, the two countries agreed to a quid pro quo: the Germans would fund approximately 60 percent of Spacelab, and the French 20 percent, in return for similar but reversed support for Ariane.[14]

The United Kingdom had less enthusiasm for supporting a wide range of major space projects than either France or Germany, preferring to concentrate on applications satellites and on cooperative scientific

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[9] Schwarz, op. cit., p. 22o.

[10] Letter from u, A, Johnson, U ,S. Under Secretary of State for Political Affairs, to Minister Theo Lefevre, Chairman of the European Space Conference, Sept. 1, 1971.

[11] See 'Launch Assurances Policy, " White House Press Release of Oct. 9, 1972; in Space *Law: Selected Basic Documents,* 2d cd., committee print for Senate Committee on Commerce, Science and Transportation, December 1978, p. 557.

[12] *World-Wide Space Activities,* op. cit., p. 1961.

[13] For detail discussion see *World-Wide Space Activities,* op. cit., pp. 293-303.

[14] *World-Wide Space Activities,* op. cit., p. 286.

programs. Though Britain strongly favored the establishment of a single European space agency, British support for ESA **hinged on the potential competition between its Geostationary Technology Satellite (GTS) and ESRO'S proposed Marots maritime communications satellite. Eventually, Britain agreed to drop its GTS in favor of becoming the Marots project leader and providing some 56 percent of the funding. It also agreed to support the Ariane and Spacelab programs, though at fairly low levels. These compromises (the so-called "Second Package Deal") were essentially worked out by July 1973, paving the way for the drafting of an** ESA **charter and the founding of** ESA in May 1975.

France

In 1960, France announced plans to build an IRBM designed to carry nuclear weapons, and an industrial consortium called SEREB was formed to build military missiles. SEREB eventually became active in civilian developments as well. In 1961, a civilian agency, the Centre National d'Etudes Spatiales (CNES), was formed under the Ministry of State for Scientific Research, Atomic and Space Affairs.

At first the French hoped for close cooperation with the United States, but the United States was reluctant to transfer its newly acquired missile technology abroad.[15] After considerable effort, the first operational French IRBM, the S-2, was deployed in 1971, and the first submarine-launched missile in 1972.

Meanwhile, CNES began work on a series of civilian launchers, the so-called "precious stones" series. The only successful launcher was the Diamant version, which in November 1965 orbited the first French satellite, the 42-kg Asterix, from the French testing grounds in Saharan Algeria. France was also a major participant in **ELDO, whose ill-fated Europa was to have used a Diamant** as its second stage. The Diamant in various versions made successful orbital flights from Algeria and later from the Kourou spaceport in French Guiana **until 1973, A large number of the satellites launched were used** for military-related geodetic work; others were for experiments in communications and atmospheric research.

The French also built satellites for launch on U.S. and Soviet vehicles; the first U.S.-launched French satellite went upon December 6, 1965 (oniy 10 days after the Asterix, suggesting that the French were understandably eager to have the first French satellite placed in orbit by a national launcher). In 1971, the Soviet Union launched a French scientific satellite, Aureole. Talks with the Soviets began in 1965 and a number of cooperative projects, including the training of two French astronauts for an upcoming Salyut mission, have taken place.

Great Britain

The British initiated a two-stage military rocket program in 1956. In 1960, the program was canceled due to a conviction that it was militarily obsolete; the "Blue Streak" first stage was then proposed as part of ELDO'S Europa launcher, of which Great Britain was initially a strong supporter.

During the 1960's Great Britain developed a number of scientific satellites known as the Ariel series, the first of which was launched by the United States in 1964. Great Britain was an active supporter of both ELDO and ESRO; in addition, it embarked in 1964 on a major launch development program known as Black Arrow. In 1971, the Black Arrow succeeded in orbiting a single 66-kg satellite, called Prospero, from the Australian test range at Woomera, following which the program was canceled. Despite the L1 1.5 million spent, the government determined that using U.S. launchers would be significantly less expensive–unlike the French, the British had no concern that the United States would balk at launching commercially competitive or military payloads. In 1969, the United States orbited the first of two Skynet geosynchronous military communications satellites.l G

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[15] *World-Wide Space Activities,* op. cit., p. 148.

[16] *World-Wide Space Activities,* op. cit., pp. 217-234.

Appendix H

INDUSTRIAL INNOVATIVE PROCESS

Innovation

If the **United States is to remain a leader** in the development and use of space technology, it will be necessary to enlist a greater share of private resources to augment the contributions of the Federal Government. In each of the four technologies dealt with in this report, the opportunities for private investment have increased dramatically in very recent times. In its attempts to encourage industrial participation, the National Aeronautics and Space Administration (NASA) has not only identified many potential commercial applications for space technology, but has developed new institutional mechanisms for increasing the flow of Government expertise and resources to the private sector. With a few exceptions, however, the private sector has remained unenthusiastic about the prospects of investing in space.

The purpose of this appendix will be to take a brief look at the process of innovation in order to establish a framework within which to discuss the issue of commercializing space technology. Because the subject of industrial innovation is complex, and highly dependent on subtle factors such as the willingness to take risks and the acuity of technical and business judgments, generalizations in this area can be deceptive. Nevertheless, it is useful to identify some of the key factors that motivate the private sector to allocate resources to the pursuit of product development and improvement.

Innovation is generally defined by economists to be the first commercial application of a new or improved product or production process. The process by which innovations are developed can be viewed as a sequence of three interdependent events. [1]

- ***Generation of an idea,*** involving the synthesis of a market need and the recognition of a technical capability for meeting that need.
- ***Problem solving*** including the setting of specific technical goals and the search for alternate methods of meeting those goals.
- ***Implementation or commercialization,*** consisting of engineering design, tooling for production, plant construction, production and marketing start-up, and first commercial introduction.

Analyzing these three stages, it becomes apparent that the management of technical innovation requires much more than the maintenance of a productive research and development (R&D) laboratory. It is a corporation-wide task that involves the skills and personalities of everyone from the scientists and engineers in the lab to the top legal and financial management. Because of this wide spectrum of interested parties, the process of project selection is highly dependent on the flow of information within the firm. The object of scientists and engineers is generally new knowledge, and they tend to focus on the problem of technical success.

Managers, on the other hand, are concerned with marketing a profitable product and therefore focus on development time, risk, and potential return on investment. This marked difference in interests and goals may result in a communication gap that prevents management from getting the technical information that it needs to assess projects accurately.[2]

This problem is particularly significant in the context of NASA's desire to involve the private sector in the commercialization of space technology. The process of project selection within a firm is already complex. When the administrative problem of coordinating NASA's management structure and technical expertise with that of the firm is added, such a project may appear unattractive. NASA'S Joint Endeavor Agreements (discussed in ch. 8) and related institutional arrangements are designed, in part, to address this problem.

The Decision to Innovate

Innovation is one means used by firms to stimulate growth and to compete with other firms within an industry. Improvements in a product or process can lead to a reduction in the costs of production or improvements in performance or quality. In this manner, innovation can increase a firm's market share, profits, or both. Innovation may also be directed to the development of new products targeted for existing or potential markets.

Innovation is not the only way, and often not the best way for individual firms to stimulate growth and to compete. These goals can also be accomplished by noninnovative methods designed to maximize sales, such as advertising or new marketing strategies, or to minimize cost, as by standardizing production techniques. A firm is also not limited to internal development, but can pursue growth and a competitive edge through merger, acquisitions, and diversification.[3]

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[1] James M. Utterback, "Innovation in Industry and the Diffusion of Technology," *Science*, vol. 183, Feb. 15, 1974, p. 621.

[2] Edwin Mansfield, *The Economics of Technical Change, 1968,* pp. 59-61.

[3] Attilio Bisio and Lawrence Gastwirt, *Turning Research and Development Into Profit, 1979,* p. 37.

Within the industrial sector a small number of specific industries make a disproportionate contribution to the total annual amount **of R&D expenditures. Table** H-1 demonstrates that five industrial categories–aircraft and missiles, electrical equipment, machinery, motor vehicles, and chemical products—accounted for over 75 percent of total industrial spending in 1978. The large interindustry differences in R&D expenditures illustrate the fact that different firms and different industries do not attach the same importance to R&D investment.

The decision by a firm to allocate resources to the pursuit of innovation can be viewed as a function of two major factors. The first is the firm's ***potential*** for innovation as dictated by external considerations such as the structure and maturity of the industry, the industry relationship with Government and the overall state of the economy. The second factor is the firm's *willingness* to innovate as dictated by internal financial, technical and human resources and the particular corporate strategy, or "personality," of the firm.

Potential for Innovation

Federal Government programs, incentives, and regulations have a significant role to play in the creation of an industry's operating environment, Federal Government support of the electrical equipment and aerospace industries is largely responsible for the fact that these two industries combined constitute almost half of the entire R&D expenditures in 1978 (table H-1). By supplying the funds or the financial incentive to conduct research, and by guaranteeing a market for new product and process innovations, the Government can encourage a level of R&D activity that would not otherwise be maintained. (This subject is discussed in greater detail later).

Of course, this is not to say that Government financial support is the main factor in stimulating industrial innovation in all industries. Certain industries, notably pharmaceuticals and chemicals, maintain very high **R&D to sales ratios and** receive very little Government support.[4] This is the result of the fact that competition in these industries is primarily based on new product development and improved product performance.

Another factor that affects the level of R&D spending is the structure of a particular industry. Whether or not it is profitable for a firm to invest in innovative activities is to some degree dictated by the number of potential rivals and the overall market profit potential. in an industry composed of many small sellers, such as home construction or brick manufacturing, the rate of innovation has been traditionally very low. This results in part from the fact that no single firm controls a significant enough portion of the market to make a sustained research endeavor profitable. Since market share directly affects revenue flow and the return that a firm may anticipate on a particular investment, firms with a small share of a particular market cannot afford to make large investments in R&D. S

Innovative activity tends to be greater in new industries and industries characterized by rapid growth and expanding markets.[6] Initially, competition in these industries is based on product quality and performance and a second-best product may have little value. However, as such industries begin to mature, competition starts to become based on price and the production process, and therefore the product becomes relatively standardized. Innovations that are pursued after this time tend to be incremental process innovations that will lower the unit costs of production. Eventually, as large investments are made in plant and equipment, manufacturers are less inclined to pursue radical innovations in either the product or the manufacturing process, as this could render their existing capital base obsolete.[7]

An interesting example of this can be seen in the U.S. satellite communications industry. Until 1973, NASA played the leading role in the development of advanced communications satellite technology. When the NASA program was phased down, it was assumed that the private sector would continue to finance and develop the communications systems necessary to meet future needs. Though the communications industry did continue to fund R&D programs, most of the research was dedicated to improving the operational capabilities and the reliability of existing systems. As a result, the U.S. satellite communications industry may face strong competition from the Japanese and the Europeans, both of whom have begun to develop the high-frequency satellite systems that may be necessary to meet the future demand for satellite communication services.

Industrial innovation is also affected by the overall health of the economy. An economy characterized by a high rate of inflation and generally volatile financial markets has an adverse effect on all types of investment but is particularly damaging to investment in innovation. Under such conditions firms show a preference for short-term, low-risk investments. Radical innovations, which by their nature are risky and often require long periods of time between concept identification and eventual commercialization, do not compete well for corporate resources.

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[4] D. Schwartzman, *Innovation in the Pharmaceutical Industry.*

[5] Mansfield, op. cit.

[6] Utterback, op. cit.

[7] Christopher T. Hill and James H. Utterback, *Technological Innovation for a Dynamic Economy,* 1979, p. 53.

Table H-1.—Funds for Industrial R&D Performance by Industry: 1968-78
(in millions of dollars)

Industry	SIC code	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978
Food and kindred products	20	184	199	230	240	259	269	298	335	355	398	431
Textiles and apparel	22,23	58	60	58	59	61	64	69	70	82	82	87
Lumber, wood products, and furniture	24,25	20	18	52	53	64	71	84	88	107	127	136
Paper and allied products	26	144	188	178	187	189	194	237	249	313	337	394
Chemicals and allied products	28	1,589	1,660	1,773	1,832	1,932	2,116	2,450	2,727	3,017	3,261	3,594
Industrial chemicals	281-82,286	965	1,007	1,031	1,009	1,031	1,119	1,299	1,391	1,524	1,446	1,570
Drug and medicines	283	398	444	485	549	607	698	807	981	1,091	1,157	1,281
Other chemicals	284-85,287-89	226	209	257	274	294	299	344	354	401	658	743
Petroleum and refining	29	437	467	515	505	468	498	622	693	767	920	,071
Rubber products	30	223	261	276	289	377	426	469	467	502	488	504
Stone, clay, and glass products	32	142	159	167	164	183	199	217	233	263	287	331
Primary metals	33	251	257	275	272	277	307	358	443	506	531	546
Ferrous metals and products	331-32,3398,3399	135	136	149	144	146	163	181	215	256	260	264
Nonferrous metals and products	333-36	115	121	126	128	130	145	177	228	250	271	282
Fabricated metal products	34	183	182	207	242	253	291	313	324	358	393	397
Machinery	35	1,483	1,546	1,729	1,860	2,158	2,549	2,985	3,196	3,487	3,952	4,459
Office, computing, and accounting machines	357	[1]	[1]	[1]	[1]	1,456	1,733	2,103	2,220	2,402	2,763	3,126
Other machinery except electrical	35 (balance)	[2]	[2]	[2]	[2]	[2]	[2]	[2]	[2]	[2]	1,189	1,333
Electrical equipmen	36	4,083	4,347	4,220	4,389	4,680	4,902	5,01	5,105	5,636	5,928	6,743
Radio and TV receiving equipment	365	55	57	70	64	48	49	51	50	52	61	54
Electronic components	367	2,520	2,670	2,604	2,731	330	406	489	549	691	746	834
Communication equipment	366					2,583	2,613	2,424	2,385	2,511	2,804	3,252
Other electrical equipment	361-64.369	1.508	1.620	1.546	1.594	1,719	1,834	2,047	2,121	2,382	2,317	2,603
Motor vehicles and motor vehicles equipment	371	1,499	1,568	,591	1,768	1,954	2,405	2,389	2,340	2,778	3,324	3,783
Other transportation equipment	373-75,379					56	72	87	90	94	121	131
Aircraft and missiles	371,376	5,765	5,878	5,219	4,881	,950	5,052	5,278	5,713	6,339	7,089	7,680
Professional and scientific instruments	38	663	742	744	746	838	961	1,075	1,173	1,331	1,466	1,689
Scientific and mechanical measuring instruments	38 ,82	8	23	131	133	63	86	22	266	325	373	452
Optical, surgical, photographic and other instruments	383-87	545	6 9	613	612	675	775	854	907	1,007	1,093	,237
Other manufacturing industries	21,27,31,39	[illegible]	121	128	13	1	58	177	205	217	250	280
Nonmanufacturing industries	07-17,41-67,737 739.807.891	603	655	705	704	707	715	768	735	845	978	52
Total		17.429	18.308	18.067	18.320	19,552	21,249	22,887	24,187	26,997	[illegible]	[illegible]06

[1] Data not tabulated at this level prior to 1972.
[2] Data not tabulated at this level prior to 1977.

SOURCE: National Science Foundation, *National Patterns of Science and Technology Resources* (March 1980).

The stimulus to innovate may also stem from critical shortages or a sharp rise in cost of the resources necessary for production. For example, intensive research on synthetic rubber was only undertaken after certain cartel agreements caused the price of natural rubber to increase dramatically.[8] A more recent example is the aerospace industry's attempts to design jet engines with greater fuel efficiency. This decision was undertaken in response to rising fuel costs and the threat of temporary fuel shortages. Rising labor costs have also contributed significantly to innovations in robotics and industrial automation.[9]

Willingness to Innovate

At the broad level of R&D strategy, individual firms must assess the relative advantages of innovation v. imitation. Innovation is attractive if being first yields a strong market position and if barriers to entry (e.g., patent protection, capital requirements, control over distribution) can be erected which limit the ability of other firms to copy or improve upon a product.[10] On the other hand, the risk assumed by the imitator is much lower, and if the innovator is very successful he may create a market large enough to accommodate the imitator. The R&D strategy of a firm can have many different orientations to the market:[11]

- First to market—based on strong R&D, technical leadership, and risk taking.
- *Follow the* leader—based on strong development resources and the ability to act quickly as the market starts its growth phase.
- ***Applications*** engineering—based on product modifications to fit the needs of particular customers in mature markets.

For each new product or service being sought or considered, the firm must also assess the effects of that product or service on the firm's present manufacturing, distribution, and office facilities. New product development can be sought to enhance an existing area of competence such as a distribution system, a production capability, or promotional skills. Such development may also be primarily defensive in character, as when a firm pursues a product in order to spread the risks of its involvement in a highly cyclical industry.

The decision of a firm to allocate resources to innovation is a subjective determination on the part of management that takes into consideration the need to innovate, the probability that a given project will be a technical and commercial success, and the financial ability of a firm to undertake the project. Although formal, quantitative project selection techniques can be used to project such factors as rates of return and pay-out periods, in the final analysis the decision to innovate is a strategic choice that depends upon a corporate manager's business and technical acumen.

Some analysts have charged that U.S. corporate managers have underestimated the need for innovation. They contend that this has resulted in the decline in innovation and productivity growth and deficits in the balance of trade. A recent article charged that

> **By their preference for servicing existing markets rather than creating new ones and by their devotion to short-term returns and "management by numbers," many (American managers) have effectively forsworn long-term technological superiority as a competitive weapon.**

Because of the existence of other factors such as inflation, tax laws, labor costs, Government regulation, fear of capital shortages, or the price of imported oil it is difficult to gauge the truth of this assessment. It is important to note, however, that to the extent that corporate managers do rely on quantitative project selection techniques, there is some evidence that such techniques tend to be biased against ambitious projects with potentially large payoffs.[13] These techniques often utilize formal market surveys to compare the estimated returns on investment for alternative projects. Reliance on such surveys can be misleading in that consumers are often unable to appreciate the value of major innovations before they are commercialized.[14] A Though major innovations may have a much greater profit potential than modest product improvements, they are more difficult to justify using formal market surveys.

This fact has important ramifications for potentially commercializable space applications. Because such projects involve both technical and market uncertainties, industry has viewed them as unattractive investment. It is difficult to assess, at this point, whether industry's cautious view of space is the result of myopic management techniques or insight based on experience in dealing with complex investment decisions.

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[8] G. W. Stocking and M. W. Watkins, Cartels **in Action, 1964, p. 73.**

[9] John **D. Fisk,** *Industrial Robots in the U. S.: Issues and Perspectives,* **Congressional Research Service, March 1981.**

[10] Bisio, op. cit., p. 37.

[11] Bisio, op. **cit., p. 38.**

[12] Robert **H. Hayes and William J. Abernathy, "Managing** Our Way to Eco**nomic Decline,"** *Harvard Business Review,* July-August **1980, p. 70.**

[13] Edwin **Mansfield, et al.,** *The Production and Application of New Industrial Technology, 1977,* **p.** *43.*

[14] Hayes, op. cit., p. 71; Hayes and Abernathy point out that: "The **argument that consumer analyses and formal market surveys should dominate other considerations when allocating resources to product development is untenable. It may be useful to remember that the initial market estimate for computers in 1945 projected total worldwide sales of only 10 units. Similarly, even the most carefully researched analysis of consumer preferences for gas-guzzling cars in an era of gasoline abundance offers little useful guidance to today's automobile manufacture in making wise product investment decisions. Customers may know what their needs are, but they often define those needs in terms of existing products, processes, markets, and prices. "**

The answers to such questions may be forthcoming as Europe and Japan target specific space technologies for commercial application.

In space applications, as well as other high-technology industries, the Government has played, and continues to play, a major role in product identification and development. It is important therefore to examine the nature of this role and Some of the methods by which it is accomplished.

Government Role in Innovation

The Government plays an extremely important role in the innovative process, particularly in the area of basic research. The impact of such financial support has been particularly significant in the aerospace, electronics and computer industries, where expensive basic research has been essential to product development. Government can provide financial support of R&D both directly and indirectly, through a variety of mechanisms. Such support does, however, raise important questions as to the appropriate roles of the public and private sectors in the development and operation of new technology. One way to address this problem is to identify the kind of benefit–public good or private good—that a new technology will provide.

A public good is one that cannot profitably be divided, priced, and sold to the individual members of a collectivity (i.e., a city, State or country). Governments traditionally have existed to provide public goods such as highways, sea and air navigation aids, and national defense. A private good, by contrast, is one that can be provided through a market transaction to those who desire it and are willing to pay the price set by the provider, Of course, it is often the case that a particular product or service produces mixed benefits, making it difficult for a private sector supplier to justify the cost of providing the benefit. In this situation, some argue that the Government should intervene to correct this lack of market incentive by using public funds to invest in technology intended for eventual use in the private sector.

Finally, and perhaps most fundamentally in the context of Government funding, the definitions of public good and private good are highly political in character. It is important to recognize that when discussing technologies that may benefit large segments of society, it is a matter of judgment and philosophy, not an issue for analytical resolution, which should be provided through Government programs and which through private activity.

The most controversial area with respect to R&D funding by the Government is that in which eventual commercialization is a major objective in the development program. Ordinarily, the private sector bears the total responsibility for funding R&D intended to be incorporated into commercial systems. However, over the past decade the Government has provided significant support, not only for basic research but also for applied research, technology and systems development, and even demonstration projects in such areas as space and energy technology.

A policy decision to support R&D in an area intended for eventual commercialization is a decision to augment or override market forces as a determinant of R&D investment. In the United States, the scientific and technological sectors that have advanced most rapidly in the 20th century, including space, are those that have received substantial assistance from the Federal Government.[15] This assistance has taken the form, among others, of direct financial support for R&D and of the creation of Government organizations to manage the research programs carried out with such support.

The establishment of NASA, and this organization's early work on communications satellites, are examples of substantial Government involvement in a commercially viable technology. Another example can be found in the development of electronic component technology. The reason for early U.S. domination of this industry is directly related to the R&D support provided by the Government. In the early 1950's, the military services, desiring to make their equipment more portable and to increase its reliability in the field, began to finance semiconductor R&Don a large scale. Between 1955 and 1961, the Government spent approximately $66 million on semiconductor R&D and production refinements.

Purchase Guarantees

In addition to direct financial support the Government may encourage innovation and the commercialization of new technologies in a number of ways, such as guarantees, technology transfers, and favorable tax treatment. One example of the influence of market guarantees can be seen in the integrated circuit industry. Though the basic inventions in this industry resulted from work done under Government contract, the technical breakthrough that allowed mass production was accomplished by Fairchild Industries without any Federal support.[16] The fact that there was a clear Government demand for these products and processes was an important factor in the firm's decision to undertake this research in the first place. Future

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[15] J. Schnee, "Government Programs and the Growth of High-Technology Industries," Research Policy, vol. 7 no. 2 (1978), p. 4.

[16] OECD, *Gaps in Technology: Electronic Components,* 1968, p. 59.

developments in remote sensing may provide another example of the importance of a Government-guaranteed market. Several plans have been proposed that envision the transfer of the Landsat system to a private sector organization. All of these plans are contingent on the Government's agreement to purchase its remotely sensed data from such an organization, thereby guaranteeing that such a venture would have a stable financial base.

Technology Transfer

In addition to providing assured product demand, it is also significant that the Government develops technologies that have either a director indirect usage in the private sector. An example of this can be seen in the computer industry. Because of Government sales in this industry companies were able to fund their R&D programs at very high levels.[17] This resulted in a rate of technological progress that exceeded that which could have occurred in a normal commercial environment. In addition, military requirements with respect to computer size, speed, and reliability far exceeded what would have been requested by the business community. As a result, the technology that was transfered to the private sector was far more sophisticated than it would have been without Government involvement. Finally, because of the military's extensive use of this new technology, the computer industry was able to overcome the natural skepticism that would have existed in the business community toward an untried product. There are many examples of technology transfers in the aerospace industry that have resulted or may result in important commercial products. The obvious examples that have been mentioned above are advanced communication systems and remote-sensing technology.

Government Regulation

Though the effects of Government regulation on innovation are not completely understood, many are of the opinion that regulation is a factor in the recent decline of innovation in the United States. A recent report by the National Research Council tended, with certain reservations, to agree with this opinion.[18] It stated that though the reasons for the decline in U.S. innovation are varied and complex, there are a number of cases (such as new pesticides, certain chemical compounds and railroad shipping services), where solid documentation existed to prove that regulation contributed to this decline. *

Government regulation can also delay the introduction of new and useful products and processes. An example of this fact can be seen in the history of the use of satellites for domestic communications. In 1963, when NASA began launching its Syncom series of satellites utilizing the geosynchronous orbit, it became apparent that the use of this orbit would have important applications for domestic communications. Yet, it was not until 1974 that commercial domestic satellite service was available in the United States. This long period between the technical realization and the commercial application of the technology was marked by scores of legal and organizational battles over systems ownerships involving the Federal Communication Commission (FCC), the Justice Department, the White House and the numerous segments of private industry who wished to use the technology. The result of nearly a decade of struggling was that FCC, in 1972, announced its multientry decision which held that any qualified entity, subject to certain conditions, could own and operate a commercial satellite system. Meanwhile, Canada had been enjoying for years a domestic satellite system built by a U.S. company and launched by NASA.[19]

In the near future, Government regulation will have a significant role to play in the development of privately owned launch systems. At present, several different agencies, each with uncertain authority, are issuing regulations that have an effect on private launches. No lead agency has been designated to address critical issues such as aerial and maritime clearance, the development of new commercial launch sites, the need for a comprehensive indemnification scheme, and methods by which to authorize and license payloads. Because of the importance of these issues both domestically and internationally, it is certain that some form of regulation will be necessary. Whether or not such regulation will encourage or hinder the flow of private capital into this infant industry is yet to be seen.

Tax Incentives

The Government may also stimulate R&D expenditures by allowing industries to use the tax system to reduce the cost of such endeavors. Three of the main incentives in the present tax system are depreciation allowances, investment tax credits, and the deductibility of R&D outlays. Depreciation allows a firm to deduct as a business expense the cost of certain assets over the period of their useful life. Investment tax credits allow firms to take a certain percentage of new

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[17] Schnee, op. cit., p. 10.

[18] locational Research Council, *The Impact of Regulation on Industrial Innovation,* 1979, p. 9.

● The NRC *report* does point out, however, that in certain instances Government regulation may act to stimulate innovation. For example, though it appears that regulation has caused R&D capital funds to be used to meet regulations, it has also had the effect of stimulating the development of new socially desirable products such as pollution-control equipment and technology.

[19] M. Kinsley, *Outer Space and Inner Sanctums,* 1976, p. 131.

investment purchases as a credit against their tax liability. Section 174 of the Internal Revenue Code permits firms to deduct total R&D outlays in the year that the expenditures are incurred.

Though the intricacies of the corporate tax system are beyond the scope of this report, a simple example is helpful to illustrate some of the ways that changes in the tax structure can create the incentive to innovate .20

Figure H-1 depicts an R&D project with a 20-year development time and a 15-year market life. It assumes a research expenditure of $1 million per year, an investment of $50 million spread over 4 years to build the manufacturing facility, and a venture success rate of 100 percent. It also assumes that the tax regulations allow a 100-percent deduction for R&D outlays, an investment tax credit of 10 percent, and a depreciable life of plant and equipment of 14 years. Taking these factors into consideration, if a firm wants to earn a 15-percent return on investment, taking into account the time value or money, it must anticipate pre-tax earnings of over $90 million. **If the tax regulations in this example are altered to allow a 150-percent deduction on** R&D outlays, an investment tax credit of 25 percent, and a 5-year depreciation on the plant and equipment, the required pre-tax earnings to achieve a 15-percent return on investment would be cut in half. Figure 5 demonstrates the effect of these changes.

Although models set forth in figures H-1 and H-2 are in many ways overly simplistic, they do point out how the tax system can be used to help firms recover the cost of their R&D efforts. By making R&D expenditures easier to recover, firms will have the incentive to invest in more and longer research and development projects.

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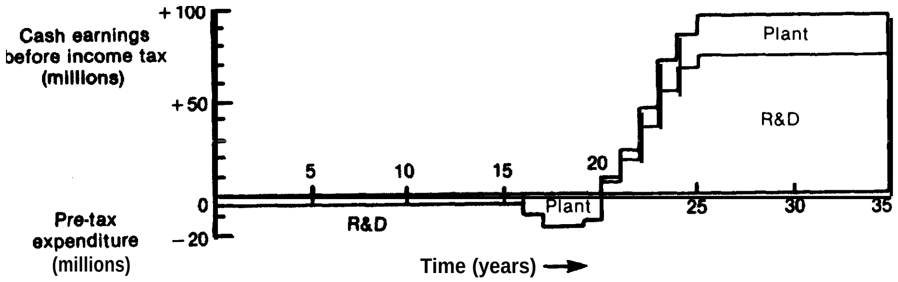
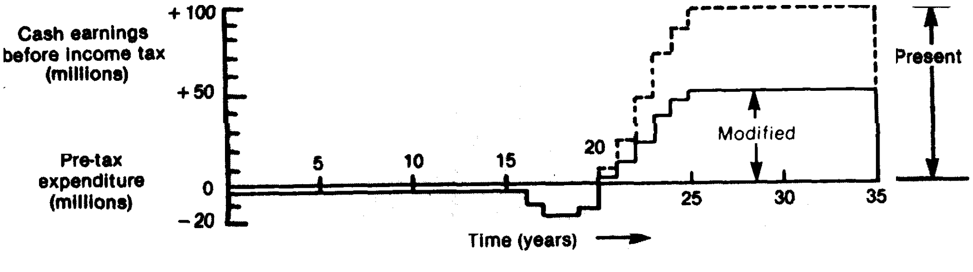
[20] John S Benjamin, statement on the Space Industrialization Act of 1979 (H. R, 2337), hearings before the Subcommittee on Space Science and Applications of the House Committee on Science and Technology, 96th Cong. 1st sess , 1979.

Figure H-1.— Results of Project Model for 20-Year Development Time



SOURCE: The Space Industrialization Act of 1979: Hearings on H.R. 2337 Before the Subcomm. on Space Science and Applications, 96th Congress, Ist Sess. 45 (1979) (statement of Dr. John S. Benjamin).

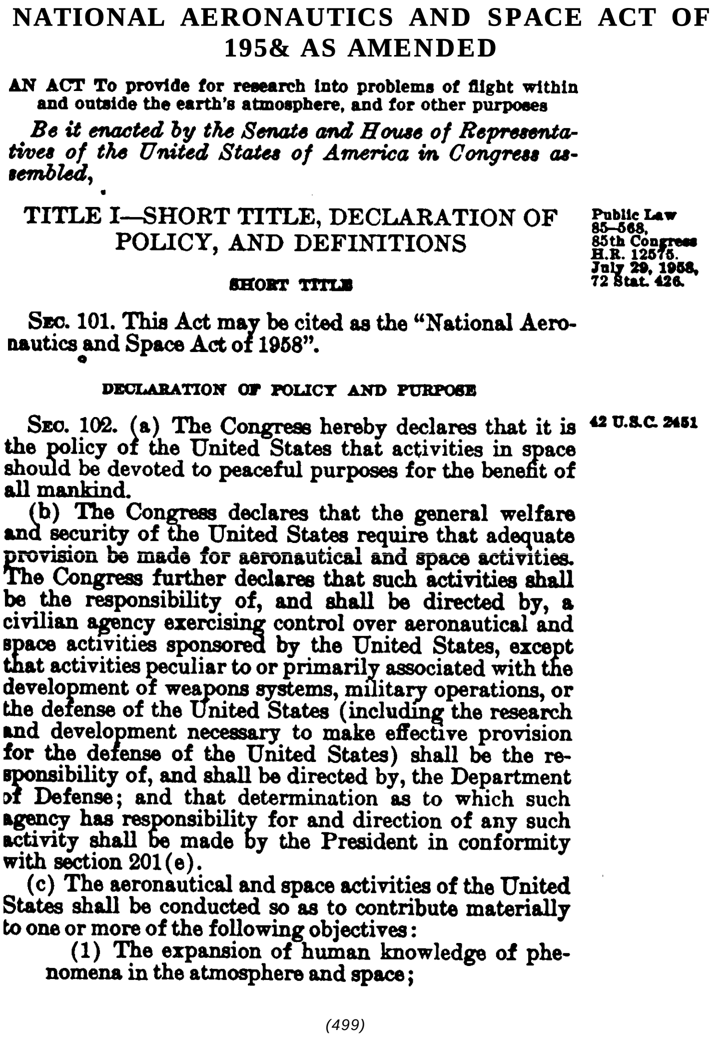
Figure H.2.—Effect of Tax Law Modifications on Project Model



SOURCE The Space Industrialization Act of 1979: hearings on H.R. 2337 before the Subcommittee on Space Science and Applications, 96th Cong., Ist sess. 45 (statement of Dr. John S. Benjamin).

Appendix I

National Aeronautics and Space Act of 1958, as Amended



NATIONAL AERONAUTICS AND SPACE ACT OF 195& AS AMENDED

AN ACT To provide for research into problems of flight within and outside the earth's atmosphere, and for other purposes

Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled,

TITLE I—SHORT TITLE, DECLARATION OF POLICY, AND DEFINITIONS

Public Law 85-568,
85th Congress
H.R. 12575.
July 29, 1958,
72 Stat. 426.

SHORT TITLE

SEC. 101. This Act may be cited as the "National Aeronautics and Space Act of 1958".

DECLARATION OF POLICY AND PURPOSE

42 U.S.C. 2451

SEC. 102. (a) The Congress hereby declares that it is the policy of the United States that activities in space should be devoted to peaceful purposes for the benefit of all mankind.

(b) The Congress declares that the general welfare and security of the United States require that adequate provision be made for aeronautical and space activities. The Congress further declares that such activities shall be the responsibility of, and shall be directed by, a civilian agency exercising control over aeronautical and space activities sponsored by the United States, except that activities peculiar to or primarily associated with the development of weapons systems, military operations, or the defense of the United States (including the research and development necessary to make effective provision for the defense of the United States) shall be the responsibility of, and shall be directed by, the Department of Defense; and that determination as to which such agency has responsibility for and direction of any such activity shall be made by the President in conformity with section 201(e).

(c) The aeronautical and space activities of the United States shall be conducted so as to contribute materially to one or more of the following objectives:

(1) The expansion of human knowledge of phenomena in the atmosphere and space;

(499)

(2) The improvement of the usefulness, performance, speed, safety, and efficiency of aeronautical and space vehicles;

(3) The development and operation of vehicles capable of carrying instruments, equipment, supplies, and living organisms through space;

(4) The establishment of long-range studies of the potential benefits to be gained from, the opportunities for, and the problems involved in the utilization of aeronautical and space activities for peaceful and scientific purposes;

(5) The preservation of the role of the United States as a leader in aeronautical and space science and technology and in the application thereof to the conduct of peaceful activities within and outside the atmosphere;

(6) The making available to agencies directly concerned with national defense of discoveries that have military value or significance, and the furnishing by such agencies, to the civilian agency established to direct and control nonmilitary aeronautical and space activities, of information as to discoveries which have value or significance to that agency;

(7) Cooperation by the United States with other nations and groups of nations in work done pursuant to this Act and in the peaceful application of the results thereof; and

(8) The most effective utilization of the scientific and engineering resources of the United States, with close cooperation among all interested agencies of the United States in order to avoid unnecessary duplication of effort, facilities, and equipment.

(d) It is the purpose of this Act to carry out and effectuate the policies declared in subsections (a), (b), and (c).

DEFINITIONS

42 U.S.C. 2452.

SEC. 103. As used in this Act—

(1) the term "aeronautical and space activities" means (A) research into, and the solution of, problems of flight within and outside the earth's atmosphere, (B) the development, construction, testing, and operation for research purposes of aeronautical and space vehicles, and (C) such other activities as may be required for the exploration of space: and

(2) the term "aeronautical and space vehicles" means aircraft, missiles, satellites, and other space vehicles, manned and unmanned, together with related equipment, devices, components, and parts.

TITLE II-COORDINATION OF AERONAUTICAL AND SPACE ACTIVITIES

NATIONAL AERONAUTICS AND SPACE COUNCIL

42 U.S.C. 2471. Establishment; membership.

SEC. 201[1] (a) There is hereby established, in the Executive Office of the President, the National Aeronautics and Space Council (hereinafter called the "Council") which shall be composed of—

(1) the Vice President, who shall be Chairman of the Council;

(2) the Secretary of State;

(3) the Secretary of Defense;

(4) the Administrator of the National Aeronautics and Space Administration; and

(5) the Chairman of the Atomic Energy Commission.

Alternate presiding officer.

(b) The President shall from time to time designate one of the members of the Council to preside over meetings of the Council during the absence, disability, or unavailability of the Chairman.

Alternate members.

(c) Each member of the Council may designate another officer of his department or agency to serve on the Council as his alternate in his unavoidable absence.

(d) Each alternate member designated under subsection (c) of this section shall be designated to serve as such by and with the advice and consent of the Senate unless at the time of his designation he holds an office in the Federal Government to which he was appointed by and with the advice and consent of the Senate.

Functions.

(e) It shall be the function of the Council to advise and assist the President, as he may request, with respect to the performance of functions in the aeronautics and space field, including the following functions:

(1) survey all significant aeronautical and space activities, including the policies, plans, programs, and accomplishments of all departments and agencies of the United States engaged in such activities;

(2) develop a comprehensive program of aeronautical and space activities to be conducted by departments and agencies of the United States;

(3) designate and fix responsibility for the direction of major aeronautical and space activities;

(4) provide for effective cooperation among all departments and agencies of the United States engaged in aeronautical and space activities, and specify, in any case in which primary responsibility for

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[1] Reorganization Plan No. 1 of 1973 (38 Federal Register 9579, April 18, 1973), abolished the National Aeronautics and Space Council together with its functions, effective July 1, 1973.

Executive secretary. Appointment and compensation of staff.

Security check.

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

U.S.C. 2472. Establishment; Administrator. SEC. 202.[2] (a) There is hereby established the National Aeronautics and Space Administration (hereinafter called the "Administration"). The Administration shall be headed by an Administrator, who shall be appointed from civilian life by the President by and with the advice and consent of the Senate. Under the supervision and direction of the President, the Administrator shall be responsible for the exercise of all powers and the discharge of all duties of the Administration, and shall have

authority and control over all personnel and activities thereof.

Deputy Administrator. (b) There shall be in the Administration a Deputy Administrator, who shall be appointed from civilian life by the President by and with the advice and consent of the Senate and shall perform such duties and exercise such powers as the Administrator may prescribe. The Deputy Administrator shall act for, and exercise the powers of, the Administrator during his absence or disability.

Restriction. (c) The Administrator and the Deputy Administrator shall not engage in any other business, vocation, or employment while serving as such.

FUNCTIONS OF THE ADMINISTRATION

42 U.S.C. 2473. SEC. 203. (a) The Administration, in order to carry out the purpose of this Act, shall—

(1) plan, direct, and conduct aeronautical and space activities;

(2) arrange for participation by the scientific community in planning scientific measurements and observations to be made through use of aeronautical and space vehicles, and conduct or arrange for the conduct of such measurements and observations; and

(3) provide for the widest practicable and appropriate dissemination of information concerning its activities and the results thereof.

(b) The Administration shall initiate, support, and carry out such research, development, demonstrations, and other related activities in solar heating and cooling technologies (to the extent that funds are appropriated therefor) as are provided for in sections 5, 6, and 9 of the Solar Heating and Cooling Demonstration Act of 1974.[2a]

Functions. (c) In the performance of its functions the Administration is authorized—

Rules and regulations. (1) to make, promulgate, issue, rescind, and amend rules and regulations governing the manner of its operations and the exercise of the powers vested in it by law;

Employees: appointment and compensation. (2) to appoint and fix the compensation of such officers and employees as may be necessary to carry out such functions. Such officers and employees shall be appointed in accordance with the civil-service laws and their compensation fixed in accordance with the Classification Act of 1949, except that (A) to the extent the Administrator deems such action necessary to the discharge of his responsibilities, he may appoint not more than four hundred and twenty-five

Excepted positions.

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[2] The Federal Executive Salary Act of 1964, P.L. 88–426 (sec. 305(12), 78 Stat. 423), repealed the language in sec. 202 (72 Stat. 429) fixing the compensation of the Administrator and Deputy Administrator at per annum rates of $22,500 and $21,500, respectively. In lieu thereof, the positions of Administrator and Deputy Administrator were placed in level II and level III, respectively, of the Federal Executive Salary Schedule. In addition, the Federal Executive Salary Act of 1964 placed en other NASA positions in designated levels of the Federal Executive Salary Schedule (78 Stat. 416 as amended, 5 U.S.C. 5311–5317). See Appendix B.

[2a] Public Law 93–409 September 3, 1974, Section 4, added this new subsection (b) and redesignated old subsection (b) as subsection (c).

of the scientific, engineering, and administrative personnel of the Administration without regard to suc laws, and may fix the compensation of such personne not in excess of the highest rate of grade 18 of th General Schedule of the Classification Act of 194 as amended, and[3] (B) to the extent the Administrator deems such action necessary to recruit speciall qualified scientific and engineering talent, he ma establish the entrance grade for scientific and engineering personnel without previous service in th Federal Government at a level up to two grade higher than the grade provided for such personne under the General Schedule established by the Classification Act of 1949, and fix their compensation accordingly;

Entrance grades; scie tific and engineering personnel.

Acquisition, construction, maintenance, etc., of property.

(3) to acquire (by purchase, lease, condemnation or otherwise), construct, improve, repair, operate and maintain laboratories, research and testing site and facilities, aeronautical and space vehicle quarters and related accommodations for employees and dependents of employees of the Administration, and such other real and persona property (including patents), or any interest therei as the Administration deems necessary within an outside the continental United States; to acquire b lease or otherwise, through the Administrator o General Services, buildings or parts of buildings i the District of Columbia for the use of the Administration for a period not to exceed ten years without regard to the Act of March 3, 1877 (40 U.S.C 34);[4] to lease to others such real and personal property; to sell and otherwise dispose of real an personal property (including patents and right thereunder) in accordance with the provisions o the Federal Property and Administrative Servic Act of 1949, as amended (40 U.S.C. 471 et seq.) and to provide by contract or otherwise for cafeterias and other necessary facilities for the welfar of employees of the Administration at its installations and purchase and maintain equipment therefor;

Lease of building

Disposal property.

Cafeterias and other facilities for employees.

Gifts.

(4) to accept unconditional gifts or donations o services, money, or property, real, personal, or mixed tangible or intangible;

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[3] Clause (A) of sec. 203(b)(2), as amended, was further amende August 14, 1964, to read as above by sec. 306(d) (78 Stat. 429) of th Federal Executive Salary Act of 1964, *supra*. Original language of clau (A) appeared at 72 Stat. 429, and previous amendments thereto appea in Public Law 86–481 (74 Stat. 153); Public Law 87–367 (75 Stat. 791) Public Law 87–793 (76 Stat. 864). For annual report to Congress, se Appendix A.

[4] Authority to lease buildings in the District of Columbia was ridded to sec. 202(h)(3), 72 Stat. 430, by Public Law 86–20, May 13, 1959 (73 Stat. 2 1). The effect of 40 U.S.C. 34 has been modified by Public Law 90–550 October 4, 1968 (82 Stat. 944).

Contracts, leases, and other transactions.

(5) without regard to section 3648 of the Revise Statutes, as amended (31 U.S.C. 529), to enter int and perform such contracts, leases, cooperativ agreements, or other transactions as may be necessary in the conduct of its work and on such terms a it may deem appropriate, with any agency or instrumentality of the United States, or with any State Territory, or possession, or with any political subdivision thereof, or with any person, firm, association, corporation, or educational institution. To th maximum extent practicable and consistent with th accomplishment of the purpose of this Act, suc contracts, leases, agreements, and other transaction shall be allocated by the Administrator in a manne which will enable small-business concerns to participate equitably and proportionately in the conduct o the work of the Administration;

Small-busine participation

Agency cooperation in use of services, equipment, etc.

(6) to use, with their consent, the service, equipment, personnel, and facilities of Federal and othe agencies with or without reimbursement, and on similar basis to cooperate with other public and private agencies and instrumentalities in the use o services, equipment, and facilities. Each department and agency of the Federal Government shal cooperate fully with the Administration in makin its services, equipment, personnel, and facilitie available to the Administration, and any such department or agency is authorized, notwithstandin any other provision of law, to transfer to or to receive from the Administration, without reimbursement, aeronautical and space vehicles, and supplie and equipment other than administrative supplie or equipment;

Advisory committees.

(7) to appoint such advisory committees as ma be appropriate for purposes of consultation and advice to the Administration in the performance of it functions;

Coordination with related activities.

(8) to establish within the Administration suc alions without regard to statutory provisions provide for the greatest possible coordination of it activities under this Act with related scientific an other activities being carried on by other public an private agencies and organizations;

Experts and consultants.

(9) to obtain services as authorized by section 310 of title 5, United States Code, but at rates for individuals not to exceed the per diem rate equivalent t the rate for GS–18;[5]

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[5] Authorization to pay at rate not to exceed $100 per diem for individuals was amended by Public Law 93–316, June 22, 1974, section 6 (88 Stat. 243).

Employment of aliens.

(10) when determined by the Administrator to be necessary, and subject to such security investigations as he may determine to be appropriate, to employ aliens without regard to statutory provisions prohibiting payment of compensation to aliens;

NASA installations, visitor facilities, concessions.

(11) to provide by concession, without regard to section 321 of the Act of June 30, 1932 (47 Stat. 412; 40 U.S.C. 303b), on such terms as the Administrator may deem to be appropriate and to be necessary to protect the concessioner against loss of his investment in property (but not anticipated profits) resulting from the Administration's discretionary acts and decisions, for the construction, maintenance, and operation of all manner of facilities and equipment for visitors to the several installations of the Administration and, in connection therewith, to provide services incident to the dissemination of information concerning its activities to such visitors, without charge or with a reasonable charge therefor (with this authority being in addition to any other authority which the Administration may have to provide facilities, equipment, and services for visitors to its installations). A concession agreement under this paragraph may be negotiated with any qualified proposer following due consideration of all proposals received after reasonable public notice of the intention to contract. The concessioner shall be afforded a reasonable opportunity to make a profit commensurate with the capital invested and the obligations assumed, and the consideration paid by him for the concession shall be based on the probable value of such opportunity and not on maximizing revenue to the United States. Each concession agreement shall specify the manner in which the concessioner's records are to be maintained, and shall provide for access to any such records by the Administration and the Comptroller General of the United States for a period of five years after the close of the business year to which such records relate. A concessioner may be accorded a possessory interest, consisting of all incidents of ownership except legal title (which shall vest in the United States), in any structure, fixture, or improvement he constructs or locates upon land owned by the United States; and, with the approval of the Administration, such possessory interest may be assigned, transferred, encumbered, or relinquished by him, and, unless otherwise provided by contract, shall not be extinguished by the expiration or other termination of the concession and may not be taken for public use without just compensation;[6]

(12) with the approval of the President, to enter into cooperative agreements under which members of the Army, Navy, Air Force, and Marine Corps may be detailed by the appropriate Secretary for services in the performance of functions under this Act to the same extent as that to which they might be lawfully assigned in the Department of Defense;

Claims against United States.

(13)(A) to consider, ascertain, adjust, determine, settle, and pay, on behalf of the United States, in full satisfaction thereof, any claim for $5,000 or less against the United States for bodily injury, death, or damage to or loss of real or personal property resulting from the conduct of the Administration's functions as specified in subsection (a) of this section, where such claim is presented to the Administration in writing within two years after the accident or incident out of which the claim arises; and

(B) if the Administration considers that a claim in excess of $5,000 is meritorious and would otherwise be covered by this paragraph, to report the facts and circumstances thereof to the Congress for its consideration;[7] and

[(14)] Repealed.[8]

CIVILIAN-MILITARY LIAISON COMMITTEE[9]

42 U.S.C. 2474. Establishment; membership.

SEC. 204. (a) There shall be a Civilian-Military Liaison Committee consisting of—

(1) a Chairman, who shall be the head thereof and who shall be appointed by the President, shall serve at the pleasure of the President.[10]

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[6] Public Law 93-74, July 23, 1973, section 6 (87 Stat. 174) added paragraph 11. Previously, sec. 402(a)(34) of the Dual Compensation Act (Public Law 88-448, August 19, 1964, 78 Stat. 495) repealed sec. 203(b)(11), 72 Stat. 431, which formerly authorized NASA "to employ retired commissioned officers of the armed forces of the United States and compensate them at the rate established for the positions occupied by them within the Administration, subject only to the limitations in pay set forth in sec. 212 of the Act of June 30, 1932, as amended (5 U.S.C. 59a)." The Dual Compensation Act (5 U.S.C. 3326, 3501, 3502, 5531-5533, 6303), effective Dec. 1, 1964, was designed to simplify, modernize and consolidate * * * the laws concerning the civilian employment of retired members of the uniformed services. * * *" Pertinent portions of the Dual Compensation Act are set forth in Appendix B.

[7] NASA, like other Federal agencies can settle claims under the Federal Tort Claims Act as amended (28 U.S.C. 2671-2680).

[8] Public Law 91-646, January 2, 1971, section 220(a)(2) (84 Stat. 1903), repealed section 203(b)(14).

[9] The Committee was abolished by Reorganization Plan No. 4 of 1965, effective July 27, 1965 (30 Federal Register 9353, July 28, 1965, 79 Stat. 1319), and its functions were transferred to the President.

[10] Previous language in sec. 204(a)(1) (72 Stat. 431) providing for compensation of the Chairman at the rate of $20,000 per annum was repealed on August 14, 1964, by the Federal Executive Salary Act of 1964, supra, sec. 305(13)(B) (78 Stat. 423). No substitute provision was made to replace the language repealed.

Resolution of differences by President.

201(e).

Chairman, service of active or retired officer.

(d) Notwithstanding the provisions of any other law, any active or retired officer of the Army, Navy, or Air Force may serve as Chairman of the Liaison Committee without prejudice to his active or retired status as such officer. Any such active officer serving as Chairman of the Liaison Committee shall receive, in addition to his pay and allowances, including special incentive pays, an amount equal to the difference between such pay and allowances, including special and incentive pays, and the compensation fixed by subsection (a)(1) for such Chairman. Any such retired officer serving as Chairman of the Liaison Committee shall receive the compensation fixed by subsection (a)(1) for such Chairman and his retired pay, subject to section 201 of the Dual Compensation Act.[11]

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[11] Sec. 304(d), 72 Stat. 432, was amended to read as above by the Dual Compensation Act, sec. 401(g), August 19, 1964 (78 Stat. 490). That part of sec. 204(d) which had referred to the compensation "fixed by subsec. (a)(1)" was repealed by sec. 305(13)(B) of the Federal Executive Salary Act of 1964, *supra* (78 Stat. 423), but it was reenacted by sec. 401(g) of the Dual Compensation Act. As noted above in footnote 10, there now is no provision fixing compensation in sec. 204(a)(1).

INTERNATIONAL COOPERATION

42 U.S.C. 2475

SEC. 205. The Administration, under the foreign policy guidance of the President, may engage in a program of international cooperation in work done pursuant to this Act, and in the peaceful application of the results thereof, pursuant to agreements made by the President with the advice and consent of the Senate.

REPORTS TO THE CONGRESS

President's annual report of activities of all agencies.

SEC. 206. (a) The President shall transmit to the Congress in January of each year a report, which shall include (1) a comprehensive description of the programmed activities and the accomplishments of all agencies of the United States in the field of aeronautics and space activities during the preceding calendar year, and (2) an evaluation of such activities and accomplishments in terms of the attainment of, or the failure to attain, the objectives described in section 102(c) of this Act.

(b) Any report made under this section shall contain such recommendations for additional legislation as the Administrator or the President may consider necessary or desirable for the attainment of the objectives described in section 102(c) of this Act.

(c) No information which has been classified for reasons of national security shall be included in any report made under this section, unless such information has been declassified by, or pursuant to authorization given by, the President.[12]

Approval by congressional committees.

SEC. 207. Notwithstanding the provisions of this or any other law, the Administration may not report to a disposal agency as excess to the needs of the Administration any land having an estimated value in excess of $50,000 which is owned by the United States and under the jurisdiction and control of the Administration, unless (A) a period of thirty days has passed after the receipt by the Speaker and the Committee on Science and Astronautics* of the House of Representatives and the President and the Committee on Aeronautical and Space Sciences of the Senate of a report by the Administrator or his designee containing a full and complete statement of the action proposed to be taken and the facts and circumstances relied upon in support of such action, or (B)

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[12] Public Law 92–68, August 6, 1971, section 7 (85 Stat. 177), repealed subsection (a) of section 206 and renumbered the remaining subsections.

* Note: The "Committee Reform Amendments of 1974," enacted October 8, 1974, changed the name of the Committee on Science and Astronautics of the House of Representatives to the Committee on Science and Technology.

each such committee before the expiration of such period has transmitted to the Administrator written notice to the effect that such committee has no objection to the proposed action.[13]

TITLE III—MISCELLANEOUS

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

Note under 42 U.S.C. 2472. Termination. Transfer of functions.

SEC. 301. (a) The National Advisory Committee for Aeronautics, on the effective date of this section, shall cease to exist. On such date all functions, powers, duties, and obligations, and all real and personal property, personnel (other than members of the Committee), funds, and records of that organization, shall be transferred to the Administration.

Procurement.

(b) Section 2302 of title 10 of the United States Code is amended by striking out "or the Executive Secretary of the National Advisory Committee for Aeronautics." and inserting in lieu thereof "or the Administrator of the National Aeronautics and Space Administration."; and section 2303 of such title 10 is amended by striking out "The National Advisory Committee for Aeronautics." and inserting in lieu thereof "The National Aeronautics and Space Administration."

National security; suspension of employees.

(c) The first section of the Act of August 26, 1950 (5 U.S.C. 22–1),[14] is amended by striking out "the Director, National Advisory Committee for Aeronautics" and inserting in lieu thereof "the Administration of the National Aeronautics and Space Administration", and by striking out "or National Advisory Committee for Aeronautics" and inserting in lieu thereof "or National Aeronautics and Space Administration".

Unitary Wind Tunnel Plan Act of 1949.

(d) The Unitary Wind Tunnel Plan Act of 1949 (50 U.S.C. 511–515) is amended (1) by striking out "The National Advisory Committee for Aeronautics (hereinafter referred to as the 'Committee')" and inserting in lieu thereof "The Administrator of the National Aeronautics and Space Administration (hereinafter referred to as the 'Administrator')"; (2) by striking out "Committee" or "Committee's" wherever they appear and inserting in lieu thereof "Administrator" and "Administrator's", respectively; and (3) by striking out "its" wherever it appears and inserting in lieu thereof "his".

Effective date.

(e)[15] This section shall take effect ninety days after the date of the enactment of this Act, or on any earlier date on which the Administrator shall determine, and announce by proclamation published in the Federal Register, that the Administration has been organized and is prepared to discharge the duties and exercise the powers conferred upon it by this Act.

Publication in F.R.

TRANSFER OF RELATED FUNCTIONS

42 U.S.C. 2453. Tranfers to NASA.

SEC. 302. (a) Subject to the provisions of this section, the President, for a period of four years after the date of enactment of this Act, may transfer to the Administration any functions (including powers, duties, activities, facilities, and parts of functions) of any other department or agency of the United States, or of any officer or organizational entity thereof, which relate primarily to the functions, powers, and duties of the Administration as prescribed by section 203 of this Act. In connection with any such transfer, the President may, under this section or other applicable authority, provide for appropriate transfers of records, property, civilian personnel, and funds.[16]

Reports to Congress.

(b) Whenever any such transfer is made before January 1, 1959, the President shall transmit to the Speaker of the House of Representatives and the President pro tempore of the Senate a full and complete report concerning the nature and effect of such transfer.

(c) After December 31, 1958, no transfer shall be made under this section until (1) a full and complete report concerning the nature and effect of such proposed transfer has been transmitted by the President to the Congress, and (2) the first period of sixty calendar days of regular session of the Congress following the date of receipt of such report by the Congress has expired without the adoption by the Congress of a concurrent resolution stating that the Congress does not favor such transfer.

ACCESS TO INFORMATION

42 U.S.C. 2454. Public inspection; exceptions.

SEC. 303. Information obtained or developed by the Administrator in the performance of his functions under this Act shall be made available for public inspection, except (A) information authorized or required by Federal statute to be withheld, and (B) information classified to protect the national security: *Provided*, That

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[13] Public Law 93–74, *supra*, section 7 (87 Stat. 175), added section 207.

[14] The last part of the third proviso of the first section of the Act of August 26, 1950 (64 Stat. 476) was repealed by sec. 5 of Public Law 89–380, March 30, 1966 (80 Stat. 95). Other portions of the Act of August 26, 1950 (64 Stat. 476) were repealed by sec. 8(a) of Public Law 89–554 (80 Stat. 632) and replaced by 5 U.S.C. 3571, 5594, 7312, 7501(c), 7512(c), 7532). 5 U.S.C. 5594 was repealed by sec. 1(34)(B) of Public Law 90–83, September 11, 1967 (81 Stat. 201).

[15] Effective close of business September 30, 1958, by virtue of proclamation of September 25, 1958. (23 Federal Register 7595, September 30, 1958.)

[16] Transfers pursuant to sec. 302 have been: Executive Order 10783, October 1, 1958, transferring from the Department of Defense the Project VANGUARD and other projects of Advanced Research Projects Agency and of Department of the Air Force relating to space activities; Executive Order 10793, December 3, 1958, transferring from Department of the Army the Jet Propulsion Laboratory (near Pasadena, California); Transfer Plan, delivered to Congress January 14, 1960, effective March 15, 1960, transferring from the Department of Defense the activities of development and research of space vehicle systems and specifically the Development Operations Division of the Army Ballistic Missile Agency (near Huntsville, Alabama).

nothing in this Act shall authorize the withholding of information by the Administrator from the duly authorized committees of the Congress.

SECURITY

42 U.S.C. 2455. Requirements.

SEC. 304. (a) The Administrator shall establish such security requirements, restrictions, and safeguards as he deems necessary in the interest of the national security.

Investigations.

The Administrator may arrange with the Civil Service Commission for the conduct of such security or other personnel investigations of the Administration's officers, employees, and consultants, and its contractors and subcontractors and their officers and employees, actual or prospective, as he deems appropriate; and if any such investigation develops any data reflecting that the individual who is the subject thereof is of questionable loyalty, the matter shall be referred to the Federal Bureau of Investigation for the conduct of a full field investigation, the results of which shall be furnished to the Administrator.

Referral to F.B.I.

Access to AEC restricted data.

(b) The Atomic Energy Commission may authorize any of its employees, or employees of any contractor, prospective contractor, licensee, or pospective licensee of the Atomic Energy Commission or any other person authorized to have access to Restricted Data by the Atomic Energy Commission under subsection 145b. of the Atomic Energy Act of 1954 (42 U.S.C. 2165(b)), to permit any member, officer, or employee of the Council, or the Administrator, or any officer, employee, member of any advisory committee, contractor, subcontractor, or officer or employee of a contractor or subcontractor of the Administration, to have access to Restricted Data relating to aeronautical and space activities which is required in the performance of his duties and so certified by the Council or the Administrator, as the case may be, but only if (1) the Council or Administrator or designee thereof has determined, in accordance with the established personnel security procedures and standards of the Council or Administration, that permitting such individual to have access to such Restricted Data will not endanger the common defense and security, and (2) the Council or Administrator or designee thereof finds that the established personnel and other security procedures and standards of the Council or Administration are adequate and in reasonable conformity to the standards established by the Atomic Energy Commission under section 145 of the Atomic Energy Act of 1954 (42 U.S.C. 2165). Any individual granted access to such Restricted Data pursuant to this subsection may exchange such Data with any individual who (A) is an officer or employee of the Department of Defense, or any department or agency thereof, or a member of the armed forces, or a contractor or subcontractor of any such department, agency, or armed force, or an officer or employee of any such contractor or subcontractor, and (B) has been authorized to have access to Restricted Data under the provisions of section 143 of the Atomic Energy Act of 1954 (42 U.S.C. 2163).

Espionage and Censorship.

(c) Chapter 37 of title 18 of the United States Code (entitled Espionage and Censorship) is amended by—

(1) adding at the end thereof the following new section:

Violation of regulations.

"§ 799. **Violation of regulations of National Aeronautics and Space Administration**

"Whoever willfully shall violate, attempt to violate, or conspire to violate any regulation or order promulgated by the Administrator of the National Aeronautics and Space Administration for the protection or security of any laboratory, station, base or other facility, or part thereof, or any aircraft, missile, spacecraft, or similar vehicle, or part thereof, or other property or equipment in the custody of the Administration, or any real or personal property or equipment in the custody of any contractor under any contract with the Administration or any subcontractor of any such contractor, shall be fined not more than $5,000, or imprisoned not more than one year, or both."

Penalty.

(2) adding at the end of the sectional analysis thereof the following new item:

"§ 799. **Violation of regulations of National Aeronautics and Space Administration.**"

Protection of NASA officers and employees.

(d) Section 1114 of title 18 of the United States Code is amended by inserting immediately before "while engaged in the performance of his official duties" the following: "or any officer or employee of the National Aeronautics and Space Administration directed to guard and protect property of the United States under the administration and control of the National Aeronautics and Space Administration,".

42 U.S.C. 2456. Permission to use firearms.

(e) The Administrator may direct such of the officers and employees of the Administration as he deems necessary in the public interest to carry firearms while in the conduct of their official duties. The Administrator may also authorize such of those employees of the contractors and subcontractors of the Administration engaged in the protection of property owned by the United States and located at facilities owned by or contracted to the United States as he deems necessary in the public interest. to carry firearms while in the conduct of their official duties.

PROPERTY RIGHTS IN INVENTIONS

42 U.S.C. 2457. Inventions made in performance of work under contract.

SEC. 305. (a) Whenever any invention is made in the performance of any work under any contract of the Administration, and the Administrator determines that—

(1) the person who made the invention was employed or assigned to perform research, development,

or exploration work and the invention is related to the work he was employed or assigned to perform, or that it was within the scope of his employment duties, whether or not it was made during working hours, or with a contribution by the Government of the use of Government facilities, equipment, materials, allocated funds, information proprietary to the Government, or services of Government employees during working hours; or

(2) the person who made the invention was not employed or assigned to perform research, development, or exploration work, but the invention is nevertheless related to the contract, or to the work or duties he was employed or assigned to perform, and was made during working hours, or with a contribution from the Government of the sort referred to in clause (1),

such invention shall be the exclusive property of the United States, and if such invention is patentable, a patent therefor shall be issued to the United States upon application made by the Administrator, unless the Administrator waives all or any part of the rights of the United States to such invention in conformity with the provisions of subsection (f) of this section.

(b) Each contract entered into by the Administrator with any party for the performance of any work shall contain effective provisions under which such party shall furnish promptly to the Administrator a written report containing full and complete technical information concerning any invention, discovery, improvement, or innovation which may be made in the performance of any such work.

(c) No patent may be issued to any applicant other than the Administrator for any invention which appears to the Commissioner of Patents to have significant utility in the conduct of aeronautical and space activities unless the applicant files with the Commissioner, with the application or within thirty days after request therefor by the Commissioner, a written statement executed under oath setting forth the full facts concerning the circumstances under which such invention was made and stating the relationship (if any) of such invention to the performance of any work under any contract of the Administration. Copies of each such statement and the application to which it relates shall be transmitted forthwith by the Commissioner to the Administrator.

(d) Upon any application as to which any such statement has been transmitted to the Administrator, the Commissioner may, if the invention is patentable, issue a patent to the applicant unless the Administrator, within ninety days after receipt of such application and statement, requests that such patent be issued to him on behalf of the United States. If, within such time, the Administrator files such a request with the Commissioner, the Commissioner shall transmit notice thereof to the applicant, and shall issue such patent to the Administrator unless the applicant within thirty days after receipt of such notice requests a hearing before a Board of Patent Interferences on the question whether the Administrator is entitled under this section to receive such patent. The Board may hear and determine, in accordance with rules and procedures established for interference cases, the question so presented, and its determination shall be subject to appeal by the applicant or by the Administrator to the Court of Customs and Patent Appeals in accordance with procedures governing appeals from decisions of the Board of Patent Interferences in other proceedings.

Board of Patent Interferences.

False representations, request for transfer of title to patent.

(e) Whenever any patent has been issued to any applicant in conformity with subsection (d), and the Administrator thereafter has reason to believe that the statement filed by the applicant in connection therewith contained any false representation of any material fact, the Administrator within five years after the date of issuance of such patent may file with the Commissioner a request for the transfer to the Administrator of title to such patent on the records of the Commissioner. Notice of any such request shall be transmitted by the Commissioner to the owner of record of such patent, and title to such patent shall be so transferred to the Administrator unless within thirty days after receipt of such notice such owner of record requests a hearing before a Board of Patent Interferences on the question whether any such false representation was contained in such statement. Such question shall be heard and determined, and determination thereof shall be subject to review, in the manner prescribed by subsection (d) for questions arising thereunder. No request made by the Administrator under this subsection for the transfer of title to any patent, and no prosecution for the violation of any criminal statute, shall be barred by any failure of the Administrator to make a request under subsection (d) for the issuance of such patent to him, or by any notice previously given by the Administrator stating that he had no objection to the issuance of such patent to the applicant therefor.

Waiver of right to inventions.

(f) Under such regulations in conformity with this subsection as the Administrator shall prescribe, he may waive all or any part of the rights of the United States under this section with respect to any invention or class of inventions made or which may be made by any person or class of persons in the performance of any work required by any contract of the Administration of the Administrator determines that the interests of the United

Inventions and Contributions Board.

States will be served thereby. Any such waiver may be made upon such terms and under such conditions as the Administrator shall determine to be required for the protection of the interests of the United States. Each such waiver made with respect to any invention shall be subject to the reservation by the Administrator of an irrevocable, nonexclusive, nontransferable, royalty-free license for the practice of such invention throughout the world by or on behalf of the United States or any foreign government pursuant to any treaty or agreement with the United States. Each proposal for any waiver under this subsection shall be referred to an Inventions and Contributions Board which shall be established by the Administrator within the Administration. Such Board shall accord to each interested party an opportunity for hearing, and shall transmit to the Administrator its findings of fact with respect to such proposal and its recommendations for action to be taken with respect thereto.

License regulations.

(g) The Administrator shall determine, and promulgate regulations specifying the terms and conditions upon which licenses will be granted by the Administration for the practice by any person (other than an agency of the United States) of any invention for which the Administrator holds a patent on behalf of the United States.

Protection of title.

(h) The Administrator is authorized to take all suitable and necessary steps to protect any invention or discovery to which he has title, and to require that contractors or persons who retain title to inventions or discoveries under this section protect the inventions or discoveries to which the Administration has or may acquire a license of use.

Defense agency.

(i) The Administration shall be considered a defense agency of the United States for the purpose of chapter 17 of title 35 of the United States Code.

Definitions.

(j) As used in this section—

(1) the term "people" means any individual, partnership, corporation, association, institution, or other entity.

(2) the term "contract" means any actual or proposed contract, agreement, understanding, or other arrangement, and includes any assignment, substitution of parties, or subbcontract executed or entered into thereunder; and

(3) the term "made", when used in relation to any invention, means the conception or first actual reduction to practice of such invention.

CONTRIBUTIONS AWARDS

42 U.S.C. 2458.

Application.

SEC. 306. (a) Subject to the provisions of this section, the Administrator is authorized, upon his own initiative or upon application of any person, to make a monetary award, in such amount and upon such terms as he shall determine to be warranted, to any person (as defined by section 305) for any scientific or technical contribution to the Administration which is determined by the Administrator to have significant value in the conduct of aeronautical and space activities. Each application made for any such award shall be referred to the Inventions and Contributions Board established under section 305 of this Act. Such Board shall accord to each such applicant an opportunity for hearing upon such application, and shall transmit to the Administrator its recommendation as to the terms of the award, if any, to be made to such applicant for such contribution. In determining the terms and conditions of any award the Administrator shall take into account—

Referral to Inventions and Contributions Board; hearing and recommendation.

Determination by Administrator.

(1) the value of the contribution to the United States;

(2) the aggregate amount of any sums which have been expended by the applicant for the development of such contribution;

(3) the amount of any compensation (other than salary received for services rendered as an officer or employee of the Government) previously received by the applicant for or on account of the use of such contribution by the United States; and

(4) such other factors as the Administrator shall determine to be material.

Apportionment of award.

(b) If more than one applicant under subsection (a) claims an interest in the same contribution, the Administrator shall ascertain and determine the respective interest of such applicants, and shall apportion any award to be made with respect to such contribution among such applicants in such proportions as he shall determine to be equitable. No award may be made under subsection (a) with respect to any contribution—

Surrender of claims to compensation.

(1) unless the applicant surrenders, by such means as the Administrator shall determine to be effective, all claims which such applicant may have to receive any compensation (other than the award made under this section) for the use of such contribution or any element thereof at any time by or on behalf of the United States or by or on behalf of any foreign government pursuant to any treaty or agreement with the United States, within the United States or at any other place;

Limitation of amount; report to Congress.

(2) in any amount exceeding $100,000, unless the Administrator has transmitted to the appropriate committees of the Congress a full and complete report concerning the amount and terms of, and the basis for, such proposed award, and thirty calendar days of regular session of the Congress have expired after receipt of such report by such committees.

42 U.S.C. 2459. Authorization of appropriations.

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[17] For requirement of prior authorizing legislation, see Appendix A, Public Law 86-45, June 15.1959 (73 Stat 75, 42 U.S.C. 2480).

[18] Subsec. (C) of sec. 307, added by sec. 6 of Public Law 88-113. September 6.1968 (77 Stat. 144).

"TITLE IV—UPPER ATMOSPHERIC RESEARCH

"PURPOSE AND POLICY

"SIX. 401. (a) The purpose of this title is to authorize and direct the Administration to develop and carry out a comprehensive program of research, technology, and monitoring of the phenomena of the upper atmosphere so as to provide for an understanding of and to maintain the chemical and physical integrity of the Earth's upper atmosphere. 42 USC 2481.

"(b) The *Congress* declares that it is the policy of the United States to undertake an immediate and appropriate research, technology and monitoring program that will provide for understanding the physics and chemistry of the Earth's upper atmosphere.

"DEFINITIONS

"SEC. 402. For the purpose of this title the term 'upper atmosphere' means that portion of the Earth's sensible atmosphere above the troposphere 42 Usc 2482.

"PROGRAM AUTHORIZED

"SEC 403. (a) In order to carry out the purposes of this title the Administration in cooperation with other Federal agencies, shall initiate and carry out a program of research, technology, monitoring, and other appropriate activities directed to understand the physics and chemistry of the upper atmosphere. 42 USC 2483.

"(b) In carrying out the provisions of this title the Administration shall-

'(l) arrange for participation by the scientific and engineering community, of both the Nation's industrial organizations and institutions of higher education in planning and carrying out appropriate research, in developing necessary technology and in making necessary ob3ervation8 and measurements;

'(2) provide, by way of grant, contract, scholarships or other arrangements, to the maximum extent practicable and consistent with other laws, for the widest practicable and appropriate participation of the scientific and engineering community in the program authorized by this title; and

"(3) make all results of the program authorized by this title available to the appropriate regulatory agencies and provide for the widest practicable dissemination of such results.

"INTERNATIONAL COOPERATION

"SEC. 404. In carrying out the provisions of this title, the Administration, subject to the direction of the President and after consultation with the Secretary of State, shall make every effort to enlist the support and cooperation of appropriate scientists and engineera of other countries and international organizations.". 42 USC 2484.

SEC. 9. This *Act* may be cited as the "National Aeronautics and Space Administration Authorization Act, 1976". **Short title.**

Approved June 19, 1975.

Abbreviations, Acronyms, and Glossary

Abbreviations and Acronyms

AACB	Aeronautics and Astronautics Coordinating Board
AIAA	American Institute of Aeronautics and Astronautics
AID	Agency for International Development
APPLE	Ariane Passenger Payload Experiment
A-sat	antisatellite
ASTP	Apollo-Soyuz Test Project
ATS	Applications Technology Satellite
BLM	Bureau of Land Management (DOI)
6SS	broadcasting-satellite services
CCAD	Crop Condition Assessment Division
CCD	charge coupled device
CCIR	International Radio Consultative Committee of the International Telecommunication Union
CCITT	International Telegraph and Telephone Consultative Committee of the International Telecommunication Union
CCT	computer-compatible tape Magnetic tape containing digital data in appropriate format.
CEPT	Conference Europeene de Postes et Telecommunications
CFE	continuous flow electrophoresis
CIFASA	French German Consortium
CLT	Campagnie Luxembourgeosie de Telediffusion
CNES	Centre National D'Etudes Spatiales, National Center for Space Research–French equivalent of NASA
COMSAT	Communications Satellite Corporation
COPUOS	Committee on the Peaceful Uses of Outer Space (United Nations)
CTA	Centro Tecnico Aerospecial (Brazil)
CTS	Communications Technology Satellite
DBS	Direct Broadcast Satellite
dBw	a measure of power, decibels referenced to 1 watt
DDR&E	Director of Defense Research and Engineering
DNS	The Department of Defense Navigation Satellite System
DOC	Department of Commerce
DOD	Department of Defense
DOE	Department of Energy
DOI	Department of Interior
DOMSAT	Domestic Communications Satellites
DSCS	Defense Satellite Communication System
EBU	European Broadcasting Union
ECS	European Communication Satellites (ESA)
EIRP	effective isotropically radiated power (measured in watts)
ELDO	European Space Vehicle Launcher Development Organization
ELV	expendable launch vehicle
EROS	Earth Resources Observation Systems
ERS	European Remote-Sensing Satellite
ESA	European Space Agency
ESRO	European Space Research Organization
FAS	Foreign Agricultural Service (of the DOA)
FCC	Federal Communications Commission
FLTSATCOM	Fleet Satellite Communication System (Navy)
FM	frequency modulation
FSS	fixed satellite service
GARP	Global Atmospheric Research Program (of the World Meteorological Organization)
GEO	geostationary orbit
GHz	gigahertz (91 billion cycles per second)
GMS	Geostationary Meteorological Satellite (Japan)
GNP	gross national product
GPS	global positioning satellite (sometimes NAVSTAR/GPS-DOD)
HDDT	high-density digital tape
HDT-A	high-density digital tapes of either MSS or RBV data that have been radiometrically but not geometrically corrected.
HF	high frequency
HLLV	heavy-lift launch vehicle
Hz	hertz; a unit of frequency equal to one cycle per second
IAF	International Astronautical Federation
ICBM	intercontinental ballistic missile
Ics	Interdepartmental Committee on Space (Canada)

IEEE	Institute of Electrical and Electronics Engineers
IFOV	instantaneous field of view
IFRB	International Frequency Registration Board
IGI	Industrial Guest Investigator
INMARSAT	International Maritime Satellite Organization
INTELSAT	International Telecommunication Satellite Organization, with 106 member-nations that own and operate the satellites in the Global Communication Satellite System
IRAC	Interdepartment Radio Advisory Committee
IRS	Indian Remote-Sensing Satellite Proposed by Indian Space Research Organization
ISAS	Institute for Space and Aeronautical Sciences Japanese (established in 1954 at the University of Tokyo)
ISPM	International Solar Polar Mission
ISRO	Indian Space Research Organization
ITU	International Telecommunication Union
JEA	Joint Endeavor Agreement
kHz	kilohertz (1 ,000 cycles per second)
KSC	Kennedy Space Center
LACIE	Large Area Crop Inventory Experiment
Landsat	Land remote-sensing satellites (formerly ERTS; Earth Resources Technology Satellites) of the series currently operated by NASA
Landsat D	The next generation of NASA's land remote-sensing satellites Follow-on spacecraft of this series will be sequentially designated Landsat D', Landsat D", etc.
LASS	The Land Applications Satellite System under consideration by ESA for a 1987/88 launch
LCP	Large Communications Platform
LEO	low-Earth orbit (up to approximately 500 km)
LOS	Land Observations Satellites being considered by Japan for 1987 launch
MHz	megahertz (10^{6} cycles per second)
MLA	multi-linear array—solid state technology for remote-sensing
MOS	Maritime Observation Satellite (Japan)
MOU	Memorandum of Understanding
MPS	materials processing space
MPTS	microwave power transmission system
MSS	multispectral scanner
MW	megawatt (10^{6} watts)
NACA	National Advisory Committee for Aeronautics
NAS	National Academy of Sciences
NASA	National Aeronautics and Space Administration
NASDA	National Space Development Agency (Japan)
NATO	North Atlantic Treaty Organization
NESS	National Environmental Satellite Service
NOAA	National Oceanic and Atmospheric Administration
NOSS	National Oceanic Satellite System
NSF	National Science Foundation
NTIA	National Telecommunications and Information Agency (DOC)
OMB	Office of Management and Budget
OTA	Office of Technology Assessment
OTRAG	Orbital Transport and Raketen Aktiengesellschaft (German private firm)
OTS	Orbital Test Satellite (European)
PRC	People's Republic of China
PRC (Space)	Policy Review Committee on Space established by Presidential directive in May 1978, to provide a forum for discussion of proposed changes to national space policy and for rapid referral of issues to the President for decision
PTT	Postal Telephone & Telegraph Agencies
RARC	Regional Administrative Radio Conference
RBV	return beam vidicon
R&D	research and development
SIC	Space Industrialization Corporation

SITE — Satellite Instructional Television Experiment (India)
SLAR — side looking airborne radar
Solaris — proposed French free-flying, automated, industrial processing station
SPS — solar power satellite
SSTO — single stage to orbit space vehicle
STEP · Symphonic Telecommunications Experimental Project (India)
STS — space transportation system
TDRSS — Tracking. and Data Relay Satellite System
TEA — Technical Exchange Agreement
TM — thematic mapper
USDA — U.S. Department of Agricukure
USGS — U.S. Geological Survey (DOI)
VHF — very high frequency
WARC – World Administrative Radio Conference (conducted by ITU)
WARC-77 – A specialized World Administrative Radio Conference that met in Geneva in the winter of 1977 to plan for the broadcasting-satellite service in the band 11.7 to 12.5 GHz
WARC-79 – A General World Administrative Radio Conference that met in Geneva in the Fall of 1979 to revise the international radio regulations of ITU.
WBTR – wide-band tape recorder
WMO – World Meteorological Organization (U. N. Agency)

Glossary

A priori planning of radiofrequencies-procedure by which frequencies and orbital locations are allotted to individual countries according to a plan negotiated by member nations and implemented by ITU.

Access fee–the charge paid by operators of ground stations for the right to receive the data transmitted from land remote-sensing satellites.

AgRISTARS–Agriculture and Resources Inventory Surveys Through Aerospace Remote Sensing. Large, cooperative, multiyear development program of the Departments of Agriculture, Interior, Commerce, NASA, and AID. Will develop, test, and evaluate ways to use remotely sensed data to produce early warnings of crop stress, crop assessments and forecasts, small-area land cover and water evaluation, and renewable and nonrenewable resource inventories.

Allocation (of frequency band) –entry in the table of frequency allocations of a given frequency band for the purpose of its use by one or more terrestrial or space radiocommunication services or the radio astronomy service under specified conditions. This term shall also be applied to the frequency band concerned.

Assigned frequency–the center of the frequency band assigned to a station.

Assigned frequency band–the frequency band within which the emission of a station is authorized; the width of the band equals the necessary bandwidth plus twice the absolute value of the frequency tolerance. Where space stations are concerned, the assigned frequency band includes twice the maximum Doppler shift that may occur in relation to any point of the Earth's surface.

Band–in radio, frequencies that are within two definite limits and are allocated for a definite purpose or service, e.g., the standard AM broadcast band.

Broadcasting-satellite service-a radio-communication service in which signals transmitted or retransmitted by space stations are intended for direct reception by the general public.

Broadcasting service-a radio-communication service in which the transmissions are intended for direct reception by the general public. This service may include sound transmission, television transmissions, or other types of transmission.

Containerless processing–a technique by which materials may be processed without a supporting container; this may be accomplished by using the microgravity environment of space or by employing such methods as ultrasonic levitation on Earth.

Data–in this document, "data" is used to specify the sensor voltage readings that are transmitted in digital format and received at the ground station. These readings must be interpreted and converted to other dimensions for most applications purposes.

Decibel–a unit for expressing the ratio of two amounts of electric or acoustics signal power equal to 10 times the common logarithm of this ratio, A ratio of 10 is 10 dB, a ratio of 100 is 20 dB, a ratio of 1,000 is 30 dB, etc.

Digital transmission—a technique that transmits the signal in the form of one of a discrete number of codes. The information content of the signal is concerned with discrete states of the signal, such as the presence or absence of a voltage, a contact in the open or closed position, or a hole or no hole in certain positions on a card.

Direct readout–the capability that allows ground stations to collect and interpret the data messages that are transmitted from satellites.

EROS Data Center—a facility that collects, processes, archives, and distributes data obtained from satellite, aircraft, and other systems, operated by the U.S. Geological Survey of the Department of interior, at Sioux Falls, S. Dak.

Earth exploration-satellite service-a radio-communication service between Earth stations and one or more space stations, which may include links between space stations, in which: 1) information relating to the characteristics of the Earth and its natural phenomena is obtained from active sensors or passive sensors on Earth satellites; 2) similar information is collected from airborne or Earth-based platforms; 3) such information may be distributed to Earth stations within the system concerned; and 4) platform interrogation may be included. This service may also include feeder links necessary for its operation.

Emission–radiation produced, or the production of radiation, by a radio transmitting station.

Fixed-satellite service-a radio-communication service between Earth stations at specified fixed points when one or more satellites are used; in some cases this service includes satellite-to-satellite links, which may also be effected in the intersatellite service; the fixed-satellite service may also include feeder links for other space radio-communication services.

Fixed service-a radio-communication service between specified fixed points.

Frequency—the number of complete oscillations per second of an electromagnetic wave, measured in hertz (Hz). One hertz equals one cycle per second.

Frequency allocation table (national)–a table in the FCC Rules and Regulations allocating bands of frequencies, in the usable portion of the radio spectrum, to radio-communication services.

Frequency of obsewation-the normal period, usually measured in days, elapsing between two sequential times at which a point on the Earth falls within the field of view of one of the spacecraft of the system.

Geostationary satellite–a geosynchronous satellite whose circular and direct orbit lies in the plane of the Earth's Equator and which thus remains fixed relative to the Earth; by extension, a satellite whose position remains approximately fixed relative to the Earth.

Geostationary satellite orbit–the orbit in which a satellite must be placed to be a geostationary satellite.

Geosynchronous satellite–an Earth satellite whose period of revolution is equal to the period of rotation of the Earth about its axis.

GSFC–Goddard Space Flight Center (NASA)

Harmful interference-interference that endangers the functioning of a radionavigation service or of other safety services or seriously degrades, obstructs, or repeatedly interrupts a radio-communication service operating in accordance with these regulations.

Illuminance–irradiance; rate of energy per solid angle measured at a given point.

Infrared (I R)–that part of the spectrum from the red end of visible light to the microwave region; that is, from about 0.7 m to 1 mm.

Instantaneous field of view (I FOV)-the field of view of a scanning instrument with the scan motor stopped.

Interdepartment Radio Advisory Committee (IRAC) —a body of 20 Federal agencies and departments that assists NTIA **in the development of the National Table of Frequency Allocations, the assignment of frequencies to stations operated by the Federal Government, and other spectrum management functions.**

Interference-the effect of unwanted energy due to one or a combination of emissions, radiations, or inductions upon reception in a radio-communication system, manifested by any performance degration, misinterpretation, or loss of information that could be extracted in the absence of such unwanted energy.

International Frequency Registration Board (IFRB)–a permanent organ of ITU with five officials elected by the plenipotentiary conference, examines notifications of frequency assignments from member-nations for conformity with the radio regulations.

International Telecommunication Union (ITU)–the U. N.-related organization with responsibilities in the field of international telecommunications including spectrum management. Present membership is 155 nations.

ITU Convention–the governing instrument of ITU that sets forth the structure and activities of the Union; only the plenipotentiary conference of ITU can amend or revise the Convention; it last met in Malaga-Torremoiinos in 1973, and will meet again in September 1982.

Large Area Crop Inventory Experiment (LACIE)–a demonstration program (1974-1977) that used Landsat and weather data to provide estimates of wheat production.

Kourou–Ariane's South American Launch Site.

Maritime radio-navigation satellite service–a radio-navigation satellite service in which Earth stations are located onboard ships.

Micron–unit of length equal to one-millionth (1 O-b) of a meter.

Microwave—a comparatively short electromagnetic wave, especially one between 100 cm and 1 cm in wavelength or, equivalently, between 0.3 and 30 GHz in frequency.

Multispectral scanner (MSS)–an instrument which provides data in four bands of the visible and near-infrared portions of the spectrum. The MSS scans a swath 185 km wide and has an instantaneous field of view (I FOV) of 80 meters.

Orbit–the path, relative to a specified frame of reference, described by the center of mass of a satellite or other object in space subjected primarily to natural forces, mainly the force of gravity.

Outer Space Treaty–the abbreviated name for the multilateral Treaty of Principles Governing the Activities of States in the Exploration and Use of Outer Space, Including the Moon and Other Celestial Bodies, which established in 17 articles general principles governing the activities in outer space of State parties to the Treaty in support of the use of outer space for peaceful purposes and for the benefit of all peoples. The United States is a party to the Outer Space Treaty, which entered into **force October 10, 1967.**

Permissible interference-interference at a higher level than that defined as permissible interference, and which has been agreed upon between two or more administrations without prejudice to other administrations.

Polarization–the electric (E) and magnetic (H) fields that comprise a propagating electromagnetic wave may be fixed in relation to Earth's horizon, or they may rotate. By convention, the vector of the E field is related to Earth's horizon: if the two are perpendicular, the wave is said to be vertically polarized;

if parallel, horizontally polarized. When the E and H fields are continuously rotating with respect to the horizon, the wave is said to be elliptically polarized.

Power density—the quantity of electromagnetic energy that flows through a given area per unit of time. Formally, power density is specified in watts per square meter (W/mz), but by tradition in biological effects studies it is usually expressed in milliwats per square centimeter (mW/cm^2).

Power flux density–a measure of the power radiated by a transmitter, used as a constraint on certain services to protect other services in a shared band.

Primary service-a class of allocation. Stations in a primary service may not cause harmful interference to stations in the same, or another primary service, and can claim protection from interference from stations in primary, permitted, and secondary services. Printed in solid capitals in the ITU table of allocations.

Propagation–the transmission of electromagnetic wave energy from one point to another.

Radar–a radio-determination system based on the comparison of reference signals with radio signals reflected, or retransmitted, from the position to be determined.

Regions of ITU–for the allocation of frequencies, the world has been divided into three regions by ITU. Exact boundaries of the regions are given in the radio regulations; a general description follows: region 1–Europe, Africa, the U. S. S. R., Turkey, the Territory of the Mongolian People's Republic, and areas **to the north of the** U. S. S. R.; region 2—North, Central, and South Americas, the Caribbean, and Greenland; and region 3–Asia, Oceania, Australia, and New Zealand.

Return beam vidicon (RBV)-cameras which essentially provide black and white TV images. Each RBV image from Landsat 3 covers an area 90 **km on a side (180** km total swath) and has an equivalent IFOV **of** 40 **m.**

S-Band–a frequency band over which MSS data are transmitted to foreign ground station operators on the reproduction or resale of Landsat standard data products.

Satellite–a body that revolves around another body of preponderant mass and that has a motion primarily and permanently determined by the force of attraction of that other body.

Satellite link–a radio link between a transmitting Earth station and a receiving Earth station through one satellite.

Satellite system–a space system using **one or more artificial** Earth satellites.

Side lobe–refers to power radiated from an antenna in a direction other than the desired direction of transmission.

Space system-any group of cooperating Earth stations and/or space stations employing space-radio communication for specific purposes.

Spectral bands–portions of the electromagnetic spectrum of energy radiated or reflected by the Earth to which spacecraft sensors are sensitive.

SPOT–Satellite Probatoire d'Observation de la Terre. This system is scheduled for launch by France in 1984 and is to contain two 3-channel multispectral/panchromatic multilineal visible spectrum array sensors. Its objectives are to develop satellite renewable and nonrenewable resource observation techniques and to develop a stereo and cartographic data archive.

Standard data products-data in prescribed form that are put through additional computer processes at the satellite ground processing facility. Two classes of standard data products are currently available—film imagery, which is convenient for those accustomed to working with maps and photographs, and computer-compatible tapes. The tape form is suitable for input to standard computers and lends itself to automated or specialized data handling and analysis.

Stereo coverage–refers to the availability of data from which the variation in the height of the surface being viewed can be determined.

Telecommunications-any transmission, emission, or reception of signals, wiring, images, and sounds or intelligences of any nature by wire, radio, optical, or other electromagnetic systems.

Thematic mapper (TM)–an instrument containing seven spectral bands, including three in the infrared region, with an IFOV **of** 30 m for all but the thermal infrared band which has an IFOV of 120 m.

Timeliness—the length of time between the observation itself and the delivery of suitable processed data to users or to the archive.

Tracking and Data Relay Satellite System (TDRSS)–a communications system to be used for the relay of data direct from Landsat to a single U.S. ground station at White Sands, N.M.

Transmission fee–a fee that could be paid by foreign ground station operators for data transmitted and received.

Value-added products-are products derived from standard data as a result of manipulation by computers

and/or interpreted in various ways to provide information about the surface of the Earth.

Wave guide–a device for transmitting and guiding radiofrequency waves.

X-band—a frequency band over which a combination signal of MSS and TM data from Landsat D will be transmitted directly to foreign ground stations.

Zone of exclusion–an area over the Indian subcontinent and south-central U.S.S.R. where direct satellite transmission to the TDRSS is physically impossible.