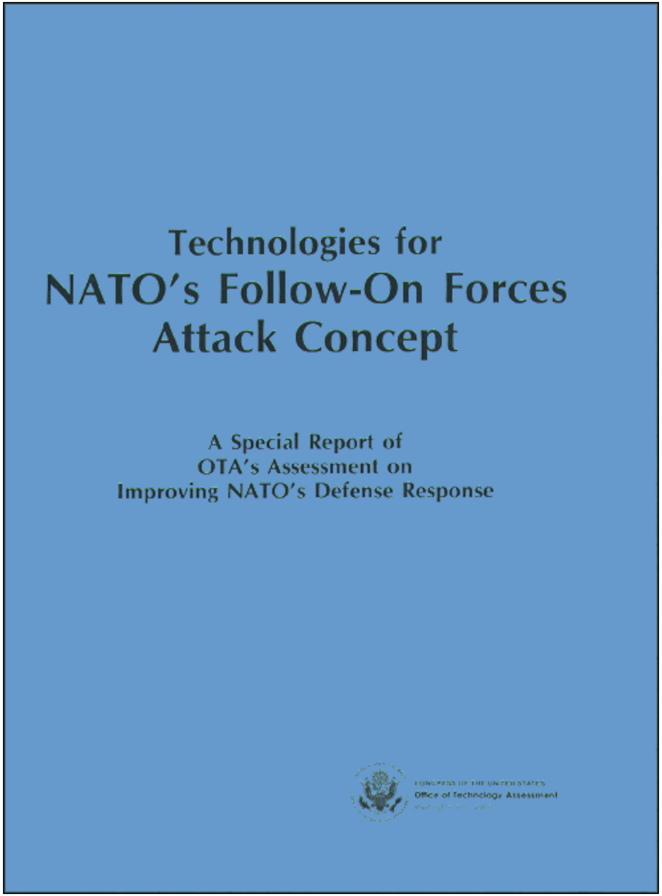
Technologies for NATO's Follow-On Forces Attack Concept

July 1986

NTIS order #PB87-100343, July 1986



Recommended Citation:

U.S. Congress, Office of Technology Assessment, Technologies for ***NATO's*** Follow-On ***Forces Attack Concept—Special Report,*** OTA-ISC-312 (Washington, DC: U.S. Government Printing Office, July 1986).

Library of Congress Catalog Card Number 86-600553

For sale by the Superintendent of Documents
U.S. Government Printing Office, Washington, DC 20402

Preface

This report is an unclassified version of OTA's Special Report, ***Technologies for NATO's Follow-on Forces Attack Concept.*** It contains primarily the executive summary of the classified report, as well as the chapter on delivery systems and munitions, with classified material removed. The detailed discussions of other areas–particularly surveillance systems and the threat–were omitted because little more than what appears in the summary could be said in an unclassified report. The classified Special Report from which this unclassified Special Report is derived may be requested by writing to:

Congress of the United States
Office of Technology Assessment
International Security and Commerce Program
(ATTN: Program Manager)
Washington, DC 20510

Also name the agency or office which can certify SECRET security clearance (please provide Social Security number) and U.S. citizenship to OTA. For congressional requests need-to-know must be certified by a Member of Congress. For other requests, need-to-know must be briefly explained.

Advisory Panel on NATO Follow-On Forces Attack Concept

Jan M. Lodal, ***Chairman***
President, INFOCEL

Gen. George S. Blanchard, USA (Ret.)

Joseph V. Braddock
Senior Vice President
The BDM Corp.

Robert Calaway
President
Resource Management International, Inc.

Seymour J. Deitchman
Vice President for Programs
Institute for Defense Analyses

Col. Victor L. Donnell, USA (Ret.)
Lockheed Missiles & Space Co.

Christopher Donnelly
Soviet Studies Research Centre
Royal Military Academy Sandhurst

Col. Patrick J. Garvey, USMCR
Post Commander, Camp Smith
New York State Division of Military & Naval Affairs

Gen. Andrew Goodpaster, USA (Ret.)

Maj. Gen. Fred Haynes, USMC (Ret.)
Director, Planning and Analysis
LTV Aerospace & Defense Co.

Lt. General Glenn Kent, USAF (Ret.)
The Rand Corp.

Ambassador Robert Komer
The Rand Corp.

Walter B. LaBerge
Vice President for Science and Technology
Lockheed Corp.

Gen. John W. Pauly, USAF (Ret.)
Chief Executive Officer
Systems Control Technology

William J. Perry[1]
Chairman
H&Q Technology Partners

Stanley Resor
Debevoise & Plimpton

Stuart Starr
Director for Planning
The Mitre Corp.

Gen. Dorm Starry, USA (Ret.)
Vice President and General Manager
Space Missions Group
Ford Aerospace and Communications Corp.

Adm. Harry D. Train, II, USN (Ret.)

John R. Transue

Col. Ralph Wetzl, USAF (Ret.)
The BDM Corp.

Maj. Gen. Ennis Whitehead, Jr., USA (Ret.)
Vice President for Analysis and Evaluation
Burdeshaw Associates

[1] Ex officio member from OTA's Technology Assessment Advisory Council.

NOTE: OTA appreciates and is grateful for the valuable assistance and thoughtful critiques provided by advisory panel members. The view expressed in this OTA report, however, are the sole responsibility of the Office of Technology Assessment. Participation on th Advisory Panel does not imply endorsement of the report.

OTA Project Staff for NATO Follow-On Forces Attack Concept

Lionel S. Johns, ***Assistant Director, OTA***
Energy, Materials, and International Security Division

Peter Sharfman, ***International Security and Commerce Program Manager***

Alan Shaw, ***Project Director***

Stephen Budiansky[1]

Michael Callaham

Allen Greenberg[2]

Peter Lert

Nancy Lubin

Administrative Staff

Jannie Coles Sandy Erwin[3] Cecile Parker Jackie Robinson

---

[1] OTA **Fellow.**
[2] **On detail from U.S. Department of State.**
[3] **In-house contract employee.**

Contents

Figures

Table

Introduction

On November 9, 1984, the North Atlantic Treaty Organization's (NATO's) Defence Planning Committee formally approved the Long Term Planning Guideline for Follow-On Forces Attack (FOFA) that had been developed ***on*** the initiative of NATO's Supreme Allied Commander Europe, General Bernard W. Rogers. Adoption of this mission concept, a major objective of General Rogers, was strongly supported by the United States. This approval set in motion an 18-month review during which NATO is analyzing how to implement this new element of its strategy for deterring a Warsaw Pact attack. This process has included, among other steps, the inclusion of follow-on forces attack in the NATO Military Committee's May 1985 Conceptual Military Framework for NATO Defence Long-Term Planning. NATO's ultimate decision will depend heavily on views that the United States and the other members of the alliance are now formulating.

Although FOFA does not represent a change in NATO's overall defensive strategy of "Flexible Response" —which will continue to rely on a balanced "triad" of conventional, theater nuclear, and strategic nuclear forces to deter a Warsaw Pact attack-it is one key element in NATO's effort to improve its conventional forces through the application of new technology. (NATO has already taken steps to strengthen the other legs of the triad, for example by deploying the nuclear-armed Pershing II and ground-launched cruise missiles in Europe, and modernizing U.S. strategic nuclear forces.)

The need to strengthen NATO's conventional leg is underscored by General Rogers's warning that:

> . . . if war broke out today, it would only be a matter of days before I would have to turn to our political authorities and request the initial release of nuclear weapons.[1]

The objective of FOFA–and of other efforts to reprove NATO's conventional capability—is to restore the flexibility to Flexible Response by assuring that NATO will be able to make a measured response to an attack by the numerically superior Warsaw Pact conventional forces, and in particular that it will retain control of the decision to escalate to nuclear weapons—that it will not be forced into an early all or nothing decision.

At the heart of the follow-on forces attack concept is the assumption that NATO's conventional forward defenses will be able to withstand an initial attack by Warsaw Pact armies in the critical Central Region —where the Federal Republic of Germany is bordered by East Germany and Czechoslovakia and where the mass of Warsaw Pact ground forces are concentrated–but that they are likely to be overwhelmed by a rapid succession of reinforcing echelons (the "follow-on forces") arriving at the battle area to exploit weaknesses created by the initial attack. General Rogers explains that the goal of follow-on forces attack is to "reduce to manageable proportions the number of Warsaw Pact forces arriving at our General Defensive Position" by attacking–with conventional weapons—''those enemy forces which stretch from just behind the troops in contact to as far into the enemy's rear as our target acquisition and conventional weapons systems will permit. "[2]

Preventing enemy reinforcements from reaching the front is not, of course, an idea new to NATO's conventional defense plans. NATO's air forces have always had the mission of "interdiction" -striking targets behind enemy lines, including follow-on forces—and even army artillery has had the capability to fire beyond the close-in battle. But what NATO has lacked until recently is the technology (or the right combinations of technologies) to find mobile targets at a distance and to hit them effectively.[3] As a result,

[1]General Bernard W. Rogers, "Follow-On Forces Attack: Myths and Realities," *NATO Review, No.* 6, December 1984, pp. 1-9.

[2]ibid.

[3]As the Air Force learned in World War II, Korea, and Vietnam, interdiction campaigns making use only of "traditional" means to locate and attack targets (reconnaissance flights and free-fall bombs) have had only limited success at best. See for example Edmund Dews and Felix Kozaczka, "Air Interdiction: Lessons From Past Campaigns," RAND paper N-1 743-PA&E, September 1981.

aircraft and other weapons systems have tended to be assigned to other missions that are likely to have a higher payoff.

Recent developments in sensors and weapons systems (loosely referred to as "smart weapons," or more generally "emerging technologies") have dovetailed with new thinking about how to exploit the vulnerabilities in Warsaw Pact ground forces operations–specifically, the rigid timing required to move up the follow-on forces and commit them to battle—to produce the follow-on forces attack concept.

ISSUES BEFORE NATO

Having adopted this concept, NATO now faces the question of making it work. In the process, NATO will have to come to grips with some difficult questions, such as:

1. Which concepts for follow-on forces attack should be pursued, and how should resources be allocated among them?
2. How much capability is needed?
3. Are dedicated forces required, and if so, what?
4. How are competing demands for procuring forces for follow-on forces attack, the close battle, and the air battle to be balanced?
5. What is to be bought? Who will produce it? Who will pay for it?
6. Will the NATO command structure and its operating procedures have to be modified?
7. Will attacking follow-on forces require changes in national intelligence policies and procedures?
8. What are the implications of possible Warsaw Pact responses to FOFA?

ISSUES BEFORE CONGRESS

Congress will be concerned with defining and funding the U.S. effort, including forces that would be assigned to NATO in wartime and the U.S. share of NATO infrastructure funding. However, FOFA is an alliance effort and the views and actions of our Allies will have to be taken into account,

Both the Army and the Air Force will be developing and procuring systems to locate targets and direct weapons against those targets, as well as the munitions and the means to deliver them. Congress will likely be faced with decisions on which of the many programs with potential applications to FOFA should be funded, and in particular whether actual procurement should proceed with technology now in hand or be deferred until further progress is made.

Several major considerations will complicate these decisions, First, **follow-on forces attack cannot be viewed in isolation;** rather, its value can only be judged in the context of NATO's overall ability to maintain deterrence and, if deterrence fails, to carry out a successful defense. Other missions–most obviously forward defense against a Warsaw Pact attack–will always play a key role in NATO's conventional defense planning.[4] Thus the value of having new capabilities to attack follow-on forces must be weighed against the value of spending that same money on NATO's other missions. Some of these missions, such as achieving air superiority (including suppression of enemy air defenses), may affect NATO's ability to attack follow-on forces,

Second, **the implementation of the follow-on forces attack concept requires the procurement and integration of a number of systems.** Congress is not faced with the relatively simple deci-

[4] The NATO Military Committee's Conceptual Military Framework for NATO Defence Long-Term Planning ". . . defines the critical warfighting mission components for alliance forces in the years ahead, including preventing a breakthrough by lead echelons of an attacking force, attacking follow-on forces, establishing and maintaining control of the sea and air, projecting maritime power and protecting allied shipping and safeguarding rear areas." Ambassador David Abshire, "NATO on the Move," *The Alliance Papers No. 6*, September 1985.

sion of whether a particular system will contribute to national security, or even with the decision of which to fund among several competitors for a particular job. Congress is faced with the complex problem of reviewing administration programs for a consistent mix of systems that will provide a viable capability to attack follow-on forces.

Third, **those decisions cannot be made solely within the context of FOFA.** Many of the systems will have other roles, both within Europe and elsewhere, that will have to be taken into account.

Fourth, **although cost will be a very important factor, it is not yet possible to determine how much a credible and effective FOFA capability will cost.** The costs of individual systems can be estimated with reasonable confidence, but estimating the potential cost of FOFA will have to await a determination of which systems are needed, and how many of each will be required. A recent report by a private study group concluded that ". . . the costs of the new programs are modest in relation to the overall current NATO defense budgets."[5] If their cost estimates are largely correct, and new developments perform as advertised, financing FOFA might significantly enhance NATO's defensive capability when compared to other uses of the same funds. While these results raise intriguing possibilities, estimates of cost, effectiveness, and technical risk will require close scrutiny. Critics are very skeptical of such estimates, and believe that costs could be very high.

Finally, decisions made by Congress **will have to take into account how the U.S. implementation of FOFA will be received by the other members of NATO.** FOFA is unlikely to be successful if it becomes a United States-only effort. The military approaches taken by each nation will have to be compatible; they will also have to be politically acceptable if the cohesion of the alliance is not to suffer. Continuing European concerns over the economic implications of defense programs and, more particularly, the need for a "two-way street" in arms sales between the United States and Europe, will be major issues.

[5] ***Strengthening Conventional Deterrence in Europe (ESECS //),*** **The European Security Study Report of the Special Panel (Boulder, CO: Westview Press, 1985).**

THE OTA STUDY

As a result of congressional interest in the issues that this NATO decision raises for the United States, the Office of Technology Assessment was asked in July 1985 to conduct a study of follow-on forces attack. The initial findings of that study are presented in this special report, The study was requested by the House Foreign Affairs and Armed Services Committees, and has the interest and support of the Senate Armed Services committee. This report discusses what the follow-on forces attack concept is and how it fits into NATO's strategy, and it introduces and explains advances in technology that may be important "or implementing the concept. Subsequent reports will expand this work in both breadth and n depth.

In its assessment, OTA has been asked by the requesting committees to:

1. survey the status of various deep interdiction capabilities and programs, including a description of programs to develop and deploy advanced conventional munitions;
2. discuss the military and deterrence rationale for having a deep interdiction capability, and assess the strengths and weaknesses of various existing and proposed alternatives;
3. review the attitudes of our NATO allies on these matters and review relevant Soviet doctrines and plans; and
4. assess the likelihood that plausible combinations of these alternatives would meet U.S.

and NATO objectives; discuss a range of reasonable policy options; discuss their pros, cons, and likely timing of availability.

The first item is the subject of this special report. A full assessment, covering all of these topics, will be delivered in February 1987.

Both this document and the final report take the adoption of the follow-on forces attack concept by NATO as a given; the purpose here is not to question the wisdom of that decision, but rather to explore options for implementing that decision and their implications. In addition, the use of chemical or nuclear weapons to attack Soviet follow-on forces is specifically excluded from consideration.

TOPICS FOR THIS SPECIAL REPORT

This report provides an overview of the U.S. technological developments of interest for FOFA. While it does not rate or rank these developments, it does describe what they are and how they might contribute to implementing FOFA. It also provides background on the role of FOFA in NATO strategy, the threat it responds to, and operational concepts for FOFA. The appendix provides a more detailed discussion of delivery systems and munitions.

Most of the details supporting this report–especially discussions of the threat, operational concepts, and surveillance systems—are classified. Those readers holding the proper clearances are referred to OTA's much longer secret report.

The discussion of Soviet doctrine presented in this report reflects the generally accepted NATO view on the subject. Other views—for example that the Soviets would plan to employ nuclear weapons from the very start of an offensive, or that Soviet conventional strategy is moving away from a strict echelonment of forces and toward greater operational flexibility–will be explored and analyzed in the final report.

TOPICS FOR THE FINAL REPORT

Analysis of the plausible options for implementing follow-on forces attack will be deferred to the final report, as will discussion of several key issues underlying that question:

The ***advantages and disadvantages of different technical approaches*** is a complicated question whose answer depends not only on technical feasibility (whether the technology will actually work) but also on the final system's reliability (whether it will continue to work under battlefield conditions and in the face of countermeasures), flexibility (whether it can be used against different targets or under different conditions from those it was designed for), effectiveness in achieving military goals in battle, and cost.

How new technologies with distinctly new capabilities would be incorporated into the NATO ***military structure*** is a separate issue, likewise complex. An important question, for example, is whether it would be necessary for all NATO corps to acquire a capability for attacking follow-on forces; another is the question of how their use would be coordinated between corps and between ground forces and air forces.

A more thorough analysis of Soviet operation: and ***likely Soviet responses*** to NATO's adoptior of follow-on forces attack is necessary to reach a conclusion about plausible options for NATO Where in the battlefield to concentrate follow on forces attack and against which targets is clearly a fundamental issue that depends in large measure on Soviet offensive strategy. And by anticipating possible Soviet responses, it should be possible to identify the more robust options.

Finally, the ***attitudes of the NATO allies*** will determine the political feasibility of options for im plementing follow-on forces attack. The European members of NATO have historically been uneasy about moves that appear to decouple the ultimate threat of nuclear escalation from the defense of Western Europe. Although General Rogers has been careful to frame follow-on forces attack in terms of "raising the nuclear threshold" and increasing the credibility of NATO's ability to escalate to nuclear weapons—rather than replacing the need for nuclear weapons—European concerns remain. Conversely, political sensitivities have always required NATO to foreswear a declaratory strategy that could be seen as "offensive"; for this reason NATO's military plans noticeably omit counterattacks that involve ground forces crossing into Warsaw Pact territory. Follow-on forces attack, by extending the reach of ground forces across borders, may well aggravate these sensitivities. And on the economic front, the European nations, already sensitive about what they see as a "one-way street" in arms sales, are concerned about the implications of a military strategy that relies even more on the advanced technology in which the United States possesses a lead.

Summary

BASIC OBSERVATIONS

The adoption of the Supreme Allied Commander Europe's (SACEUR's) follow-on forces attack (FOFA) concept is an effort to enhance deterrence by dealing with a potential vulnerability–the risk that even if the North Atlantic Treaty Organization's (NATO's) forces could largely withstand the initial attack by the Warsaw Pact's first echelon, pact follow-on forces could overwhelm by sheer numbers, or could exploit tactical advantages to penetrate into NATO's rear. It does not reflect a downgrading of other missions such as fighting the close battle. Although NATO has always sought a capability to delay, disrupt, or destroy such follow-on forces, the means to do so have been limited. NATO's adoption of the FOFA concept reflects a recognition of new opportunities to carry out this mission—both through new technology and through the development of new procedures to take advantage of existing capabilities.

Although NATO could attack follow-on forces using the systems currently in the inventory, realizing the full potential of the concept is usually linked to exploiting emerging technologies–especially those associated with gathering the information required to attack the targets (reconnaissance, surveillance, and data handling), and advanced weapons concepts. **The technologies of primary interest are now relatively mature, and could result in fielded systems over approximately the next decade.**

In considering how best to support the FOFA concept, there are several basic points which bear on many congressional decisions:

- **procurement of systems ought to be tied to clearly defined operational concepts.** It is important to understand how the job is to be done before buying the tools to do the job. However, concept development should be rooted in an understanding of what is technically feasible.
- **Systems ought to be considered not individually, but as complete packages to support specific operational concepts.** The process of attacking follow-on forces is a complicated one, with many steps between initial detection of the target and successful attack. It requires a number of different systems to perform different functions compatibly. Since failure to buy one or two could greatly reduce the value of investments in the others, it is important to treat them in groups.
- **Component systems will have to be procured in sufficient quantities.** It is likely that large numbers of targets will have to be engaged. If attacking follow-on forces is to aid NATO's defense, the capacity will have to exist to attack enough to make a difference. If having this capability is to aid deterrence, it should be apparent to the Soviets that NATO has this capacity.
- **Some systems will be "key systems."** Failure to procure them will greatly reduce the ability to implement the concept.
- **Some redundancy may be desirable.** Complicated systems that have to perform many consecutive functions are subject to disruption in many ways. Redundancy in some of those functions reduces the vulnerability.
- **Practice and training will be important.** The process of attacking follow-on forces is likely to be complex, as are many of the systems used to support it. Facilities to train commanders and operators will be of value.

It is largely up to the Department of Defense (DOD) to-provide Congress with lists of what systems the services require and how many of each are needed. This report provides a framework for understanding the plans that DOD submits to Congress. It reviews the place of FOFA in NATO strategy, outlines operational concepts, and reviews the developments of particular interest for attacking follow-on forces.

BACKGROUND: NATO STRATEGY AND THE THREAT TO THE CENTRAL REGION

NATO's Flexible Response strategy, adopted in 1967, rests on conventional, theater nuclear, and strategic nuclear forces. It is a strategy for deterrence based on the idea that:

> The price of an attack on Western Europe must remain the possibility of triggering an incalculable chain of nuclear escalation.[1]

NATO–which does not want a nuclear war any more than the Warsaw Pact does—would resist a conventional offensive with conventional forces, but would reserve the option for deliberate escalation should its conventional defense be unsuccessful. NATO's conventional defense must "provide a reasonable prospect of frustrating a conventional attack."[2]

Soon after the founding of the Alliance in 1949, it became clear that for economic and political reasons NATO would not deploy the number of army divisions and combat aircraft that studies showed were required to meet the threat posed by Soviet forces in Central Europe. NATO's solution to this shortfall in conventional forces was to introduce nuclear weapons. Nuclear weapons compensated for NATO's disadvantage in conventional firepower, and reduced the burden of maintaining large conventional forces. Moreover, the threat of a nuclear strike against Warsaw Pact armies gave NATO two distinct strategic advantages. It forced the Warsaw Pact armies to disperse in order to reduce their vulnerability to a nuclear strike, which limited their ability to conduct an offensive strategy based on concentrating massive forces against a prepared defense. And by confronting the Soviets with the incalculable risk that a conventional attack could set off a chain of escalation leading to nuclear destruction of Soviet territory, it provided NATO a deterrent that relied less on the possibility of actually having to fight an intensely destructive modern war on NATO territory.

[1]General Bernard Rogers, "Follow-On Forces Attack (FOFA): Myths and Realities," *NATO Review,* December 1984, pp. 1-9.
[2]Ibid.

Soviet gains in nuclear weaponry led NATO in 1967 to adopt a new strategy, Flexible Response, which remains in effect today. Flexible Response relies on a "triad" of conventional, theater nuclear, and strategic nuclear forces designed to maintain the credible possibility that a war could become nuclear and escalate to a strategic nuclear exchange; that credibility is supported by a conventional capability which is strong enough that NATO would not be forced into an early decision to use nuclear weapons.

Two important factors govern NATO strategic thinking. First, both nuclear and conventional capabilities are essential; neither one can substitute for the other. Second, as a defensive alliance, NATO is precluded from adopting an aggressive, offensive military strategy.

These major strategic considerations, along with the threat and the realities imposed by geography, shape the current situation in Europe. The major threat to NATO comes from the continental forces of the Warsaw Pact, concentrated in Central Europe along the eastern border of the Federal Republic of Germany (West Germany). in the Central Region, NATO lacks "strategic depth," while facing an adversary with extreme strategic depth and the ability to use that depth to bring large land forces to bear in an offensive.[3] While the territory of the Warsaw Pact extends thousands of kilometers (km) back into the Soviet Union, it is less than 500 km from the inter-German border to the English channel. Moreover, the loss of substantial portions of West Germany, a major NATO land power in this Central Region, would be extemely serious for NATO.

The Warsaw Pact has adopted a "blitzkrieg" strategy that appears to be aimed at defeating NATO conventionally before NATO could decide to escalate to the use of nuclear weapons.[4] This

[3]One important aspect of strategic depth, especially from the defender's perspective, is the ability to trade space for time, to fall back when attacked in order to organize a responsive defense and to counterattack. Great depth was exploited in this way by the Russians against the offensives of Napoleon and, much later, Hitler.
[4]Some analysts believe that a Soviet offensive could be nuclear from the outset.

strategy depends on a ground offensive in which the initial attack is likely to be followed by succeeding waves, or echelons, of follow-on forces, all supported by air power.

Echeloning forces in-depth attempts to overwhelm a defense by bringing fresh forces against defenders exhausted by the preceding wave. Soviet doctrine calls for a carefully timed and coordinated attack, with each succeeding echelon committed at the time and place where it could be most effective in exploiting the success of its predecessor and extending the Warsaw Pact advance deeper into NATO territory. This permits the Soviets to assign individual units specific preplanned objectives and a schedule for achieving those objectives. It avoids moving massive amounts of men and equipment forward just prior to an offensive, thus avoiding giving NATO unambiguous warning of attack and overloading available roads. In the Central Region, where West Germany borders East Germany and Czechoslovakia, NATO would face a massive Warsaw Pact ground offensive that could involve over 100 divisions.

Depending on how they fit into the offensive plan, some follow-on forces would start from just behind the initial attack forces, others would begin farther back in East Germany, Poland, and Czechoslovakia, and still others would begin in the U.S.S.R. Those farthest back would be transported by rail or by road. Closer in they would group into combat units and proceed under their own power toward the battle.

NATO has a much smaller number of divisions in place in the Central Region or able to deploy there rapidly; the only immediate prospects for reinforcement would be from three French divisions in West Germany that might be assigned to NATO in wartime[6] and from several U.S. divisions which could arrive by air. NATO's only other reinforcements—some 20 U.S. Army and National Guard divisions plus one Canadian brigade–would arrive only much later, primarily by sea, and in some cases only after mobilization and training.[7]

Within the Central Region, eight army corps of five nations—West Germany, Belgium, The Netherlands, Great Britain, and the United States —are each assigned the responsibility of defending a specific sector along the border that divides West Germany from East Germany and Czechoslovakia. A Canadian brigade is also garrisoned in the Central Region. Each national corps (or other unit) has its own structure, equipment, and national doctrine; only in time of war are they assigned to a unified NATO command structure. The northern corps form the northern army group (NORTHAG) under the command of a British general; those in southern Germany form the central army group (CENTAG) under a U.S. general. Each army group is supported by a multinational Allied Tactical Air Force (2ATAF in NORTHAG, 4ATAF in CENTAG); the commanders of 2ATAF (COM2ATAF) and 4ATAF (COM4ATAF) report to the Commander of Allied Air Forces Central Europe (COMAAFCE). COMAAFCE, in turn, reports to the Commander-in-Chief, Central Region (CINCENT), a German general to whom the commanders of CENTAG and NORTHAG also report. Finally, the entire European theater–which includes the northern and southern regions as well—is under the command of SACEUR, a U.S. general.

A major consequence of NATO's structure is that the Soviets are free to allocate their forces to best advantage, and are likely to concentrate in the sectors they believe to be the weakest—particularly the Dutch and Belgian sectors in NORTHAG–while NATO's ability to shift its ground forces across corps sectors is limited.

Attacking follow-on forces is a specific defensive response to the Warsaw Pact strategy, within the context of NATO's posture. If NATO's defending forces successfully resist the initial attack, they might be in danger of being overwhelmed as successive waves of fresh forces joined the at-

[5]Although these numbers provide the basis for a rough force comparison, there are many detailed differences between a NATO division and a Warsaw Pact division; they are not strictly equivalent units.

[6]France withdrew from the NATO military structure in 1966 and has not formally committed itself to providing troops for the common defense of NATO territory.

Though not counted in the NATO force totals, there are in addition some 10 French army divisions and 13 French reserve divisions as well as West German, Belgian, and Dutch home-defense militias that could assist NATO.

tack. However, if the schedule of the offensive could be upset and the rate of introduction of fresh Warsaw Pact forces limited by delaying, disrupting, and destroying the follow-on forces, then the defenders would have a better chance of defeating each successive echelon as it arrived. Some believe that destroying the coherence of the offensive would be sufficient to cause it to fail.[8]

NATO's planners and commanders will have to decide how to allocate assets among the close battle, the follow-on forces attack, and the air battle. What forces the member nations provide will determine the NATO commanders' flexibility in making those allocations. Allocating resources to attacking follow-on forces would affect the success of the close battle, but would reduce the assets available for the close battle. Similarly, airplanes not used to attack follow-on forces might be used to suppress air defenses (which would facilitate attacking follow-on forces), provide close air support for the close battle, or defend NATO aircraft against Pact air strikes.[9]

[8]It is important to note that some observers believe Soviet doctrine is becoming more operationally flexible; while echelonment would still perhaps remain the favored strategy, commanders might be given the flexibility to allocate forces between first and second echelons according to the circumstances.

[9]Not all aircraft could fill all these roles. Procurement decisions will affect the commanders' future flexibility to allocate.

CONCEPTS FOR FOLLOW-ON FORCES ATTACK

Several general concepts for attacking follow-on forces have been suggested. NATO has some capability to implement each of these now, but that capability is limited and might be improved dramatically by suggested measures. These concepts, described below, are:

- ***Long-Range Attack.*** Attack follow-on forces deep in the enemy rear where they are lined up in transit on trains or roads. The advantage of this is that the enemy forces are concentrated and vulnerable, and their locations are relatively predictable. However, it may be difficult to know what is being transported on any particular train.
- ***Intermediate-Range Attack.*** Closer in, identify and attack critical enemy forces that are particularly threatening to a NATO corps sector within a day or two. This would allow NATO to concentrate its fire in a way that would most directly affect the success of the Warsaw Pact's next move.
- ***Cross-Corps Support.*** In the event of an attack concentrated against one or a few NATO corps sectors, attack heavily the follow-on forces in the threatened sectors using the long-range attack capabilities of other corps.

The specific targets would include groups of tanks and other less heavily armored combat vehicles, as well as surface-to-surface missiles, air defenses, command posts, and support vehicles. Some of these are fixed, some are movable, and others are highly mobile. Most are soft, others are hard. In order to be able to attack these targets effectively, it would also be necessary to take actions against targets—such as air defenses—that might restrict NATO's capability to conduct surveillance and to strike into enemy territory.

Within these overall approaches, there is some disagreement about which targets ought to be hit in order to most effectively delay, disrupt, or destroy a given Soviet force element. Some argue that the tanks are the most important targets. Others maintain that all the combat elements are important, and that concentrating on killing tanks—which is relatively difficult—is not necessary. Some argue that disrupting command and control is the most effective way to stop the offensive, while others would attack logistics and supply. Still others argue that disrupting the Soviet schedule is the heart of FOFA, and that the most effective way to attack is to concentrate on creating chokepoints, which might also facilitate effective attacks on the force elements themselves.

Finally, some believe that because timing is critical, what gets hit is not as important as hitting, for example, a command post, or a bridge, or a tank battalion just when the Soviets need it most.

Many specific operational concepts can be formulated within these general concepts, Several are discussed below. There are several general themes that run through this discussion of operational concepts. First, the closer an enemy force is to the area of the immediate battle, the more immediate is its threat. inflicting a given amount of damage or imposing a given amount of delay will be more significant for forces about to be committed to battle. At shorter ranges, NATO's ability to find targets with its tactical surveillance systems and to attack them with ground or air force weapons is also much greater. As the range to target increases, the number of surveillance and attack systems that can reach the targets decreases, the time between detection and attack may increase, and the attrition suffered in reaching the targets may also increase.

The second major point, however, is that at long ranges the targets–primarily forces being transported by rail–become more predictable and easier to localize, and this fact may well compensate for the lack of surveillance coverage.

Finally, operational concepts for follow-on forces attack do not exist in a vacuum. Other missions are likely to be crucial for their success—in particular the suppression of enemy air defenses.

Intermediate-Range FOFA

Within 150 km, prime targets for follow-on forces attack are the armored combat units which pose the most immediate threat to NATO's defensive position. Throughout the war, new forces would arrive in this band after being transported from farther East by truck or rail; thus the forces in this band—wherever their starting point—would continue to be key targets for follow-on forces attack as they always will represent the Warsaw Pact's immediate capability to add to the offensive. An attack that imposes a delay of 12 hours or more in the movement of a unit through this band could cause a significant disruption in the Warsaw Pact schedule for prosecuting the immediate battle.

There are three general mission concepts for attacking forces in this range band: attacking units on the move on roads, attacking them while stopped, or attacking them while stalled in "traffic jams" created at chokepoints. Furthermore, creating chokepoints or attacking specific facilities such as command posts could have value in their own right by delaying or disrupting the advancing forces.

When on the move under its own power, an armored combat division would, if possible, move on three or four parallel routes. A division moving over roads could stretch over 40 km. A surveillance system that can distinguish between armored vehicles and trucks (there are roughly twice as many trucks and other light vehicles as armored vehicles; among the armored vehicles, there are three times as many light-armored vehicles as tanks) could increase the value of the resulting attack.

Divisions on the move could be expected to stop from time to time. These stops could be short, necessitated by considerations such as traffic control or emergency repairs; moderately long stops for food and rest; or very long stops while waiting to be committed to the battle.

Chokepoints might be created by dropping key road bridges or sowing minefield. The Warsaw pact units attempting to move forward could pile up at these points, disrupting their schedule and presenting a concentrated target for further attack. C^3 facilities, particularly those associated with traffic control and river crossings, are also valuable targets under this concept. Although chokepoints are fixed targets whose locations are known ahead of time, the optimal timing of an attack may well depend on being able to monitor the movement of the follow-on forces so that the chokepoint will have the greatest effect.

Some more specific targets in this range band are also of interest—in particular surface-to-surface missile units and command posts. They are, however, more difficult to locate and identify.

60-901 0 - 86 - 2

Air Attack

Under current procedures, NATO army group commanders (on advice of the corps commanders) would provide the NATO regional Allied Air Force Commander, COMAAFCE,[10] with requests for air support and lists of target priorities. COMAAFCE must weigh these requests against competing demands for aircraft (e.g., air-to-air combat missions or attacks on enemy airfields) and apportion weights of effort to each category of missions. Specific target lists are identified by the corps commanders, and missions are allocated to them by the ATAFs in coordination with the army group commanders. In general, the closer to engaged ground forces the attacks are to take place, the more weight is given to specific targets nominated by the corps commanders. " This planning, which would determine in general terms the numbers of aircraft required, their ordinance loads, and where they would go, would routinely occur well in advance of the actual attack. There would then follow more detailed preparations, in which particular aircraft are assigned to each mission (which may require putting together a "package" of aircraft from several different tactical units in a coordinated attack), the aircraft are loaded and fueled, and the crews are briefed. There is considerable flexibility within this system, however, to reallocate aircraft on the basis of new information received up until take off, and to a lesser degree, even after take off. In addition, the U.S. Army and Air Force are pursuing a number of initiatives under the recent Memorandum of Agreement to improve coordination in locating and carrying out attacks against deep targets.

In the case of the mobile follow-on force targets, up-to-date information on the target location would have to reach the pilots as close to the actual attack as possible. The longer the time lag between target location and attack, the lower is the probability that the aircraft will find its target.

Aircraft are able to compensate, to some degree, for a lack of precise target-location information by placing a human observer on the scene; on-board targeting equipment can further compensate. However, the heavy Warsaw Pact air defenses, especially those that move with the combat units, limit the flexibility aircraft may exercise in searching for an imprecisely located target.

Attacking aircraft thus need to be able to minimize their exposure to air defenses. Air-to-ground missiles that allow aircraft to remain some distance from the target; munitions that are more effective and which can engage several targets per pass; and targeting systems that allow the aircraft to launch its weapons without making an initial pass to search for the precise target location can all assist in attaining this goal. This latter can be accomplished either by systems that can communicate real-time target location data to aircraft in flight to the target, or by sensors carried on board that give the aircraft a greater autonomous capability to find an imprecisely located target.

Surface-to-Surface Missile Attack

Planning an attack with Army weapons such as surface-to-surface missiles can be less complicated; the procedures for allocating and packaging aircraft for an attack are avoided. Some coordination with the air forces would however be necessary to make sure that missile firings do not interfere with air operations and to avoid duplication of effort. Moreover, targeting information may come from Air Force systems.

Precise and timely target location information is, however, more essential in the case of ground-launched weapons: current missiles cannot search for targets as airplanes can. If missiles are to be used against armored combat units moving on roads, an attack location would have to be preselected based on advance observation 01 the moving units; the missile would be launched

---

[10] The commander, Allied Air Forces, Central Europe (COMAAFCE) is the air component commander for the Commander-in-Chief, Central Region (CINCENT). COMAAFCE is "dual-hatted" (he "wears two hats"): he is also the Commander-in-Chief, U.S. Air Forces in Europe (CINCUSAFE).

[11] United States procedures are specified in Joint Operational Concept, Joint Attack of the Second Echelon (J-SAK) (TAC Pamphlet 50-26, TRADOC Pamphlet 525-16, U.S. REDCOM Pamphlet 525-4, Dec. 13, 1982). Close air support sorties are distributed to corps. Battlefield air interdiction sorties are flown against targets identified and prioritized by the Army. Air interdiction targets are selected from those nominated by the Air Force and those nominated by the Army to meet the joint commander's interdiction strategy.

when the units are observed to reach a point that would place them at the attack location when the missile arrives several minutes later. This timing may not be critical if the target is a long column of vehicles. Sensors that can distinguish between tracked and wheeled vehicles could increase the value of these attacks, given an effective antiarmor munition.

Cross= Corps Support

One important new possibility raised by follow-on forces attack is that one corps could use its long-range attack capabilities to support another corps, adding a flexibility that is currently possessed only by the air forces. Warsaw Pact forces may well concentrate their attack on the weaker NATO corps–particularly the Dutch and Belgian corps assigned to defend areas in the northern half of Germany, where the level terrain adds to their vulnerability. The Warsaw Pact attack in other sectors would then aim just to tie up the other corps and prevent them from moving to reinforce the weak points.

The United States and German corps are the best equipped to hold their forward defensive positions even without attacking the follow-on forces facing their corps sectors; they are also the most likely to be equipped in the future with a capability to attack follow-on forces. However, if some corps are to fire across corps boundaries in support of others, procedures would have to be developed by which the Army Group commander tasks the individual corps (which actually own the weapons) and coordinates fire across corps sectors. Today, NATO corps routinely plan cross-corps support with artillery.

Long-Range FOFA

At depths of greater than 150 km or so, the follow-on forces–second-echelon armies and second-echelon fronts—do not represent as immediate a threat. And an equivalent attack against the forces in this band is less quickly felt in the immediate battle: because the forces are farther away from commitment, they have greater leeway to repair damaged vehicles or otherwise compensate for damage caused by an attack. The ultimate objective is nevertheless the same: to control the rate of arrival of fresh forces at the immediate battle area.

The general mission concepts involve attacking divisions on trains; attacking railroad facilities such as generating stations and bridges; and, as in intermediate-range FOFA, attacking units on roads.

Trains moving across Poland are difficult to detect; doing so would require satellites or airplanes that penetrate deep into Warsaw Pact territory.[12] But the very large number of trains required for moving many divisions forward might present regular and predictable targets with a high density of high-value armored vehicles.[13]

Railroad facilities offer a number of suitable targets. The seven railroad lines that cross Poland from the Soviet Union have few north-south interconnections. Dropping the railroad bridges that cross the Oder-Neisse Rivers could thus create an effective obstacle. Other fixed targets include railroad generating stations, the railroad signal-control system, off-loading areas where the units shift from rail to road, and the transshipment points along the Polish-Soviet border.

Attacking units on the roads or in assembly areas poses problems similar to those discussed above for attacks at intermediate range, but compounded by the greater range and by the probability (which increases with range) that armored vehicles will be interspersed with trucks. The armored fighting vehicles are likely to be carried on transporters rather than moving under their own power. Greater range makes finding the units more difficult, and severely limits the numbers of existing aircraft that can reach these targets; and given current air-to-ground weapons that require a close approach to the target area, attacks at long range would also increase aircraft exposure to enemy air defenses.

As with intermediate-range FOFA, there are in addition a number of specialized targets of interest: command posts, nuclear weapons facilities, surface-to-surface missile units, and C^3 facilities.

Virtually all of the surveillance data in this band will have to come from national sensors, espe-

[12] Over-the-horizon radar might also provide some capability.
[13] There is, however, some controversy about this Point.

cially satellite-based systems. Making that information available to NATO poses a number of problems, some technological and some procedural (such as U.S. security regulations that govern the release of national sensor data to foreign countries), However, as noted above, units being carried by train may present continuous and predictable targets; other targets are fixed, such as bridges and power stations. While sensitive surveillance data may help to make a decision about when best to launch an attack against such targets for maximum effect, such data are not required in order to know that these targets are there.

An essential requirement is that the delivery system have sufficient range; most of the long-range band is reachable only by strategic bombers, although much is also within range of certain fighter/bombers (F-1 11s and Tornados). This situation will not change in the near future. Bomber crews would have to be trained for such a tactical mission. At the direction of higher U.S. authorities, the Strategic Air Command would make the bombers and crews available to NATO.[14] The problem of enemy air defenses is serious; at long range most escort aircraft (which could protect the bombers from enemy interceptors and could attack or electronically jam air defenses) lack the range to accompany the attack. A long-range air-to-ground missile that would allow the bombers to remain out of range of enemy antiaircraft missiles would provide the greatest assurance of survivability. Short-range air-to-ground missiles could keep the bombers away from at least the terminal defenses around heavily defended points, such as power stations and bridges.

For attacking divisions being transported by trains, such a missile would need sensors capable of following the rail lines and detecting trains. Effective submunitions, capable of both derailing the train and destroying the armored and unarmored vehicles on the trains, would also be required.

[14] SAC now maintains a liaison with USAFE and with SHAPE to facilitate tasking these aircraft. Their role is not necessarily limited to attacking at long ranges.

REQUIREMENTS, CAPABILITIES, OPPORTUNITIES

Each of these concepts requires the following general elements: 1) **surveillance and target acquisition** systems to identify and locate the targets; 2) timely **analysis and dissemination** of the information to permit planning attacks; 3) timely **command** decision allocating attack assets to targets; 4) **platforms** to deliver the weapons to the targets; 5) **control** of the platform to the location of the target at the time it arrives; 6) **weapons** that can engage the targets; 7) **munitions** that can destroy the targets; and 8) **survivability** of airplanes and their bases, ground-based launchers, and surveillance systems, so that operations can continue. Since there are great numbers of individual vehicles, it would be important for each weapon to be able to engage several targets. Developments that limit the exposure of NATO aircraft to enemy defenses would also be important. Because attack of follow-on forces is likely to require many sorties throughout the war, it cannot tolerate high attrition rates.

In the Central Region, NATO currently has a substantial number of airplanes that might be used for attacking follow-on forces. Although these aircraft have the potential to deliver thousands of tons of ordinance per day, their ability to effectively attack follow-on forces is limited by: the ability to provide and exploit target information in a timely manner, the number of individual targets each aircraft could engage per sortie, the ability of the munitions to kill the targets, the ability to control weapons to targets, and the ability to operate at night and in bad weather. There is some capability in all these areas, but much room for improvement. Furthermore, it is unlikely that all these aircraft would be devoted to attacking follow-on forces. Although some aircraft might be dedicated to that mission, others would have the flexibility to carry out other missions, such as providing a favorable enough air situation to make attacking follow-on forces attractive In addition, many of NATO’s interdiction aircraft are dual capable; some number of them will be withheld to stand nuclear alert.

Within about 30 kilometers, follow-on forces could also be attacked with artillery or the Army's multiple launch rocket system (MLRS). Several Allied nations also plan to acquire MLRS. Targeting could be supported by the Aquila RPV (remotely piloted vehicle; a small unmanned aircraft controlled from the ground), or by other Army systems such as the OV-1D Mohawk airplane. Several of the Allies also operate RPVs.

A number of measures that have been suggested for improving NATO's ability to attack follow-on forces are described qualitatively below. In the next few years improvements might be obtained by altering operational procedures and procuring sufficient quantities of existing systems. Systems that have undergone significant development–some currently in development and others unfunded—could be available in the late 1980s or early 1990s. In the far term, developments now in relatively early stages might be exploited.

Although the application of developmental systems is described here on the assumption that they will work as advertised, there is always risk associated with development. Many of the systems have been tested to varying degrees, but neither complete concepts nor the complete process of attacking follow-on forces, from target identification to destruction, have been tested under anything approaching wartime conditions.

Many of the developments discussed here have applications beyond follow-on forces attack. Their overall value should be judged within a wider context.

Near-Term Opportunities

In the near term, the following steps might improve follow-on forces attack capability. To some extent these are all being done now. Many are procedural and might be done at low cost. However, they require effort, and are not without risk of unsatisfactory outcome:

- continue to develop and exercise procedures to strike targets deep in Warsaw Pact territory using FB-111s or B-52s carrying conventional weapons;[15]
- develop procedures to provide the output of some intelligence systems to tactical users sufficiently quickly to support engagement of follow-on forces;
- develop procedures for command and control of attack aircraft and army weapons that are sufficiently responsive to support attack of follow-on forces;
- extend procedures for cross-corps support with ground-launched weapons to include MLRS,[16] and in the future ATACMS;[17]
- procure sufficient numbers of existing weapon systems that would be useful for attacking follow-on forces, in particular the MLRS, GBU-15,[18] and the tactical munitions dispenser;[19] and
- improve training for planning and execution.[20]

Currently NATO has little capability to strike very deep against divisions being transported forward by rail and road. These are attractive targets because the units would be all lined up, and would exist in such high density along a few well-defined routes that detailed surveillance might not be required to guide the attack airplanes to the targets. Few airplanes–primarily the F-1 11s which have many other tasks—can strike sufficiently deep. Using FB-111s or B-52s (trained and equipped by the Strategic Air Command and operating under SACEUR's operational control) could provide a major increase in the amount of ordinance that could be delivered against these

[15] SAC has offices at USAFE and SHAPE to faci litate the tasking of these aircraft. As these aircraft are replaced in the strategic bomber force, they could be used to augment the firepower available to SACEUR.

[16] MLRS is the Army's mu ltiple launch rocket system.

[17] Army Tactical Missile System. See append ix for description.

[18] GBU-15 is an Air Force weapon: a guided glide bomb. Once released from the airplane, it can be "flown" by a weapon systems operator in the airplane by means of a data link that transmits a TV picture from the weapon's seeker to the airplane and transmits guidance controls from the weapon systems operator in the airplane to the weapon.

[19] The tactical munitions dispenser is dropped from an airplane. It breaks open in flight and drops submunitions. Several types of munitions are available for use in dispensers, and others are under development.

[20] For example, by using the training facilities of the Warrior preparation Center near Ramstein Air Base in West Germany.

targets.[21] Existing guided bombs like the GBU-15 (or future powered and otherwise improved versions such as the AGM-130) might be used to attack important fixed targets and perhaps trains, and munitions dispensers with currently available submunitions could destroy many types of vehicles, but not the most modern tanks. Buying enough munitions would be a key to success. Timely information from national intelligence systems that can see deep into enemy territory might improve capability to find trains or columns in road march, and cut down on search time and exposure to enemy air defenses. However, since current air-to-ground weapons require aircraft to come close to the target in order to attack it, these aircraft would still have to penetrate air defenses both enroute and in the vicinity of the target.

Within about 1 so km of the close battle, information on enemy maneuver units (e.g., tank battalions) provided by tactical reconnaissance aircraft may be incomplete, and late when attack aircraft reach expected target locations.[22] (The same limitations would apply to ground-launched weapons; NATO, however, currently has ***no*** ground-launched weapons with a range comparable to that of aircraft.) Furthermore, many of the weapons carried by NATO's attack aircraft have relatively low kill rates against large numbers of vehicles, especially against armored vehicles. Several are limited by darkness and weather conditions, as are most of NATO's airplanes. The tactical munitions dispenser could provide a capability to destroy a few soft and lightly armored vehicles per sortie, while the guided bombs could improve capabilities against fixed structures and other important single targets. The multiple launch rocket system could provide the army some capability to engage follow-on forces located by corps reconnaissance systems, but its range is limited; it, too, is limited by its current munition, which has a low kill rate against heavy armor.

NATO nations–especially the United States–have intelligence gathering systems that can gather important information on potential targets. That information does not generally go directly to NATO tactical users. If it must go through a lengthy sanitization process, it will be too old to be of much value. Developing procedures for making intelligence information available on a timely basis could be important for attacking follow-on forces.

Attacking mobile follow-on forces will place demands on NATO's command structure. Procedures will have to be in place to assess surveillance information, decide what to do, task attack aircraft or ground-launched weapons while the targets still have value, and get timely target location information to the attackers so that they can find and attack them. For the past several years, the U.S. Army and Air Force have been working on joint measures to streamline this process.[23]

Midterm Opportunities

Current Programs

Several systems that are expected to reach maturity during the next several years could have important implications for attacking follow-on forces. These will require substantial funding, and many of the programs still have problems awaiting resolution:

- ASARS II synthetic aperture radar surveillance system;[24]
- PLSS emitter location system;
- Joint STARS moving target radar and weapon control system;
- products of the Joint Tactical Fusion program (e.g., ASAS and ENSCE) as well as other C^3 improvements;
- F-1 SE;
- LANTIRN navigation and targeting system for tactical aircraft;
- Army TACMS ballistic missile;

[21]See "NATO Deploys Boeing 6-52s in Deep-Strike Attack Exercise," *Aviation Week and Space Technology,* Sept. 9, 1985.

[22]That does *not mean* that the targets would never be found, or that all reports would be very old. Judicious coordination of reconnaissance and attack aircraft, when conditions permit, can greatly reduce the delay. Stopped vehicles may remain stopped many hours. Finally, aircraft vectored toward the predicted location of a division on the move are likely, after some searching, to find all the targets they can handle.

[23]See, for example, joint Operational Concept, Joint Attack of the Second Echelon (TAC Pamphlet 50-26, TRADOC Pamphlet 525-16, U.S. REDCOM Pamphlet 525-4, Dec. 13, 1982), 1982, and the Memorandum of Agreement on U.S. Army-U.S. Air Force Joint Force Development Process (May 22, 1984). This MOA covers developmental programs as well as procedures.

[24]One ASARS II prototype is currently flying.

- smart antiarmor submunitions, such as Skeet and SADARM and the MLRS/TGW;
- AGM-130 missile;
- RPV/TADARS, an Army reconnaissance and target designation system; and
- various electronic warfare capabilities and IFF (identification friend or foe) to enhance the capability of NATO forces to penetrate into enemy airspace and return safely.

The ASARS II, PLSS, and Joint STARS systems are designed to provide surveillance data on fixed, emitting, and mobile targets, respectively, to properly equipped users. Based on aircraft flying nominal patterns over NATO territory, they would see targets in enemy territory.[25] The systems developed under the Joint Tactical Fusion program (probably available after ASARS II, PLSS, and Joint STARS) would correlate these data—as well as data from other sources such as reconnaissance aircraft and RPVs—into a coherent picture of enemy activities. This could be used as part of the general situation assessment leading to identifying the most threatening enemy units and planning attacks. With more direct links to aircraft and missile launchers, the sensor systems could be used to update target location information up until the attack aircraft take off, or the army launches a missile. Target update information might also be sent directly to attacking aircraft in flight. If all this works, it would provide NATO the capability to identify the most important targets, plan its strikes accordingly, and be fairly confident that most of the attacking aircraft would find their targets, provided that NATO forces were properly equipped to receive and exploit the information. The weapon control implicit in sending updates directly to the attacking aircraft would be similarly important. It would minimize the amount of searching an aircraft would have to do in order to locate its target, and hence minimize its exposure to enemy air defenses. It would facilitate successful attack by aircraft lacking sophisticated target acquisition systems, such as the LANTIRN.

LANTIRN is a two pod system designed to fit several aircraft including both the F-1 6 and the F-15E (a version of the F-15 designed for ground attack and having greater range/payload capability than the current F-1 6). The LANTIRN navigation pod will provide the capability to navigate at low altitude at night, while the targeting pod will find targets, and lock weapon seekers onto them. it would expand the area that the pilot can see, enhance his capability to detect a target, and give him a capability to search for targets in the dark.

Loading dispensers with smart antiarmor submunitions would improve NATO's ability to exploit this improved data by allowing each sortie to engage groups of vehicles. A proper weapon mix would also include dispensers loaded with submunitions for attacking vehicles other than tanks, and dispensers loaded with mines. The AGM-130, a powered version of the GBU-15, would provide greater standoff for the launch aircraft. It could be useful in attacking trains, vehicles on roads, major air defense sites, or other fixed facilities that might be defended with local defenses.

The availability of these airborne capabilities will depend on the survivability of NATO's airfields, among other factors.

The Army TACMS (ATACMS) missile will have the capability to engage targets well beyond the range of MLRS, either in front of a NATO corps, or laterally to support another corps. If target location updates are received just prior to launch, and if effective submunitions are provided, it will be capable of engaging moving targets as well as fixed or stopped targets. It will provide the theater commander a capability in addition to that provided by the Air Force. This maybe especially important early in the conflict when requirements for aircraft sorties are high and heavy Warsaw Pact air defenses–not yet suppressed–may restrict operations.

Other Midterm Opportunities

Other measures that have been explored over the past few years might produce greater benefits from these systems. One is a target update link from the Joint STARS directly to an ATACMS or air-launched missile in flight, to further reduce target location uncertainty.[26] Another is the pro-

[25] Actual range would depend on location and altitude of patrol.

[26] Direct updates to air-launched missiles have also been considered.

vision of antiarmor submunitions for the ATACMS, currently planned for later production models. These two taken together could give the ATACMS the ability to attack targets such as tank battalions. A version of the ACM-130 that carried a submunition dispenser was under development but plans for procurement have now been dropped. If loaded with antiarmor submunitions and combined with a seeker to follow rails or roads, this could provide the capability to destroy vehicles on rails or road march. It might provide all attack aircraft with greater ability to stand off beyond defenses while attacking.[27] The LOCPOD, a powered dispenser being developed by a multinational consortium, might play a similar role.

Far-Term Opportunities

Most of the developments discussed above would be expected to enter procurement during the next few years. Given typical procurement patterns, their impact would begin to be felt during the 1990s, although in some cases inventories might not be filled until after the turn of the century.

Some problems would still remain. There has been concern over the survivability of PLSS, ASARS, and Joint STARS. The aircraft that carry these systems could be vulnerable to rapid progress in Soviet air defenses. Associated ground sites and the airfields from which NATO aircraft operate could also be vulnerable to attack. If follow-on forces attack were to depend on these systems, losing one or more might seriously degrade capability, as would moving patrol stations west to reduce vulnerability. Similarly, attack aircraft attempting to penetrate into Warsaw Pact territory can be expected to face increasingly capable air defenses; and all attack systems, with the exception of strategic bombers based in the continental United States, would be subject to prelaunch attrition.

Ideas have been proposed for addressing these problems. Some are highly classified. More survivable platforms are being studied. Using long-range cruise missiles would enhance the survivability of attack aircraft, but probably at a price—cruise missiles have proved expensive. Variants of existing missiles, the JTACMS, and the multinational NATO Long-Range Stand-off Missile are possibilities. For attacking deep into Pact territory, B-1s might be more survivable than B-52s, but would probably be less available.[28]

There has been concern that developments in Soviet armor might greatly reduce the effectiveness of new antiarmor submunitions. Programs are currently underway to explore improvements in armor and methods for defeating advanced armor.

[27] The B-52 Conventional Stand-off Capability program is investigating putting target acquisition systems on 6-52s.

[28] B-52s could become available as B-1s replace them for strategic nuclear missions. B-1s could become available without reducing strategic forces if and when they are replaced by the Advanced Technology Bomber. Of course, a decision to send some of SAC's bombers to support SACEUR rather than hold them for nuclear missions is always possible.

"PACKAGING" CONCEPTS

A complete concept, or system, for follow-on forces attack should be considered as a "package" of individual systems, each of which has a different job. For example, a package must at least include system elements for performing target acquisition and weapons delivery, as well as effective munitions. They all have to be there and operate for the concept to work. In deciding what to fund, Congress may want to suggest that DOD present complete packages, so that the effectiveness of the entire concept can be analyzed and the utility of each component can be readily understood. This approach would help Congress understand: the full extent of what has to be procured, when the full capability might be in place, how limited the capability would be until various elements were procured in sufficient quantity, and what the consequences might be of not procuring particular pieces (or failure of developments to meet expected goals). For some elements of a package there may be several candidate systems to choose among. For others, there will be only one viable choice, and failure to obtain it could have serious consequences for the viability of the package.

As a simple example, a package might include a LANTIRN-equipped F-16 that carries a tactical munitions dispenser and receives information from Joint STARS, ASARS II, and PLSS.[29] A joint tactical fusion facility would assimilate target information and pass data to automated command and control facilities supporting planning, tasking, and execution. The munitions dispenser can be loaded with either Skeets–an antiarmor submunition—or the Combined Effects Munition, which is effective against personnel and vehicles other than modern tanks. This entire package might be available in quantity by the mid to late 1990s, and–if everything works as advertised–would be capable of successfully attacking tank battalions as well as other maneuver units. Other elements would also be needed to make the system complete. **This example is illustrative only; it is not an OTA recommendation.** Other packages might be as capable.

[29] Both Joint STARS and LANTIRN improve the capability of the F-1 6 to find the target. The joint STARS decreases the area it has to search–by updating the target location—and the LANTIRN increases its capability to search the area. The closer to the target Joint STARS updates the airplane, the less it has to search. LANTIRN also provides the ability to navigate at night and in bad weather, which would be important with or without Joint STARS targeting information.

REPRESENTATIVE REMAINING QUESTIONS

Besides the obvious question of how well all these developments will work, especially in the presence of Soviet efforts to counter them, several important questions remain to be answered. First, for a given level of effort, how successful can NATO expect to be in attacking follow-on forces, and indeed how is success to be measured? How does success in attacking follow-on forces translate into success overall, and how successful does follow-on forces attack have to be? How do we balance striking very deep (i.e., against rail lines in Poland) versus attacking those forces that pose an immediate threat? Since the assets used to attack follow-on forces will generally come at the expense of forces to fight the close battle-either sorties diverted or money not spent on other systems—how do we gauge and balance follow-on forces attack against the close battle?[30] How will NATO's capabilities degrade as parts of its ability to attack follow-on forces are lost–either through attrition or through lack of funding?

[30] This is not to say that an ability to attack follow-on forces can only be obtained by reducing force structure in other areas (although some have stated that doing so would be a cost-effective trade). FOFA capability will be obtained by extending the interdiction capability of the Air Force to include a significant capability against the forces themselves, and extending the range of the Army's firepower and the ability to use it successfully against moving forces. However, the funds used to extend these capabilities will then not be available for other applications, and the systems tasked to attack follow-on forces in wartime will not be simultaneously available for other missions. For example, funds spent procuring TACMS missiles are not available to be spent on tank modernization, or air defense, or additional antitank guided missiles. An F-16 sortie flown to attack follow-on forces 100 km deep means one less F-16 sortie available to fly air defense, or to attack enemy air bases. In weighing alternative applications of the same resources, it will be necessary to consider how each would affect the outcome of the war. The effect of the reduction in one area will have to be weighed against the effect of the improvement in another within some framework that takes both into account.

Appendix

Delivery Systems and Munitions

Two major areas of development are of particular interest for the follow-on forces attack (FOFA) concept: reconnaissance, surveillance, target acquisition, and data handling; and munitions and delivery systems. Little can be said about the former in an unclassified report. This appendix provides information on munitions and delivery systems.

A weapon system is a combination of a delivery system and a munition. The delivery system—an aircraft, a missile, or an aircraft launching a missile—needs to have several general capabilities if it is to be of use in follow-on forces attack:

- **range:** FOFA targets will be located anywhere from 30 km back to as far as the Polish-Soviet border, some 800 km from the inter-German border;
- **accuracy:** depending on the target and the munition, the delivery system must be able to land a munition to within anywhere from 100 m or so to less than 1 m of the target; and
- **survivability:** aircraft and missiles must be able to reach the target (and aircraft must make the return trip as well) without getting shot down.

The choice of delivery system ranges from a manned aircraft flying directly over the target and dropping a munition, to a ground-launched missile that flies autonomously to the target. In between are a range of possibilities involving missiles launched from aircraft at increasingly longer "standoff" distances. As that distance increases, the survivability of the aircraft increases, but the time during which the missile must fly autonomously increases as well—which means less capability against targets which can move between the time the missile is launched and the time it arrives over the point at which it was aimed, unless the missile receives mid-course target location updates. Ground-launched missiles eliminate the aircraft altogether, but are vulnerable before launching–missile launchers will be high-priority targets for the Warsaw Pact. A manned aircraft is also able to compensate for imprecise target-location information and for the movement of targets by placing a human observer on the scene. Short-range missiles can incorporate relatively simple guidance systems that offer substantial improvements in accuracy over free-fall munitions; but at longer ranges, providing high accuracy becomes a complex engineering challenge.

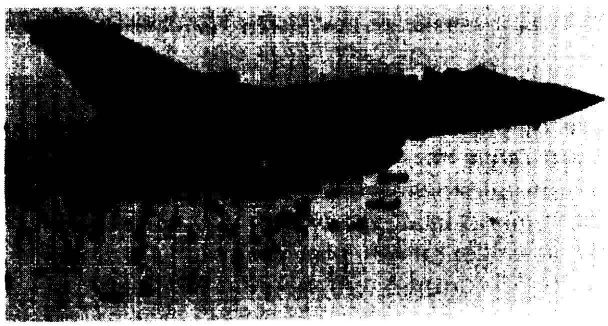
Munitions for follow-on forces attack can be as simple as conventional high-explosive bombs. But improvements in two general areas can significantly increase the usefulness of a munition in follow-on forces attack:

- **kill radius:** a conventional 500-lb high-explosive bomb must land within a meter of a tank to put it out of action; a munition with a greater area of effect need not be delivered so accurately and may in addition be able to engage multiple targets; and
- **lethality:** hardened targets, such as armored vehicles and reinforced concrete command posts, are becoming resistant to conventional high explosives; moreover, a more sophisticated lethal mechanism that uses smaller amounts of explosives increases the number of targets that can be killed per pound of aircraft or missile payload.

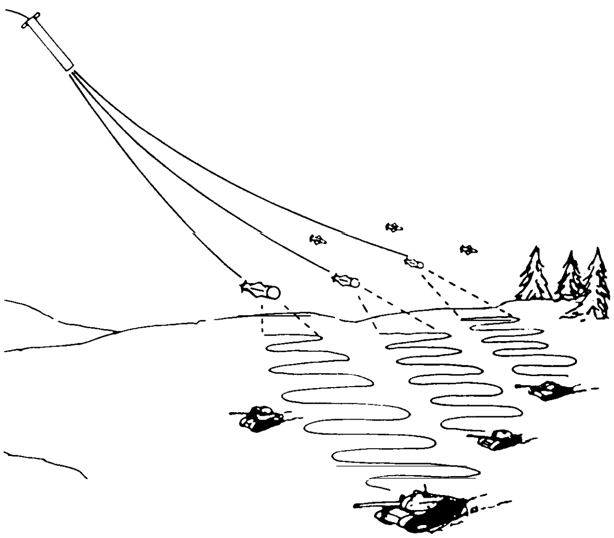
Munitions concepts are, broadly speaking, variations on three themes: unitary explosives, such as bombs and artillery shells; cluster weapons, which contain many small "submunitions" that blanket a large target area; and "smart" submunitions that search out an area with electronic sensors and selectively engage the targets they find. Figure A-1 illustrates these approaches.

Although it is often convenient, as above, to separate delivery systems from munitions—and indeed that is the way procurement requests are presented to Congress—the two elements do in fact form a complete, interacting system. Choices in one determine the range of choices available for the other, An inaccurate missile, for example, could not use a munition with a very small kill radius. On the other hand, a munition capable of engaging multiple targets per pass could inherently increase the delivery system's surviv-

Figure A-1.—Munitions Concepts



(a) MW-1 Dispenser releasing "dumb" submunitions



(b) Terminally guided submunitions frying out to seek targets

SOURCES: Photo—MBB Corp. (Messerachmitt-Bokow-Blohm (GmbH)); drawing—General Dynamics Pomona Division.

ability by reducing the number of sorties required to kill a given number of targets. The effectiveness of any one component can be measured only by examining how well the entire system functions.

Delivery Systems

Aircraft

Historically, only aircraft have been able to reach the sorts of depths behind enemy lines required to attack follow-on forces. "Air interdiction"—the Air Force's term for attacking ground targets beyond the immediate battle area—is however just one of several missions that NATO's air forces are charged with carrying out, a fact reflected in the capabilities and relative numbers of the various aircraft now in the inventory.

The United States aircraft that can play a part in follow-on forces attack fall into three general categories:

1. long-range ground-attack fighter/bombers (F-111 and future F-15E);[1,2]
2. multi-purpose fighter/bombers that, as competing demands permit, could assume some ground-attack missions (F-4 and F-16); or
3. strategic bombers which could be designated-to support NATO (B-52, FB-111, and future B-1 B).

Aside from the obvious question of range (see figure A-2), a number of factors determine the suitability of an aircraft for follow-on forces attack missions:

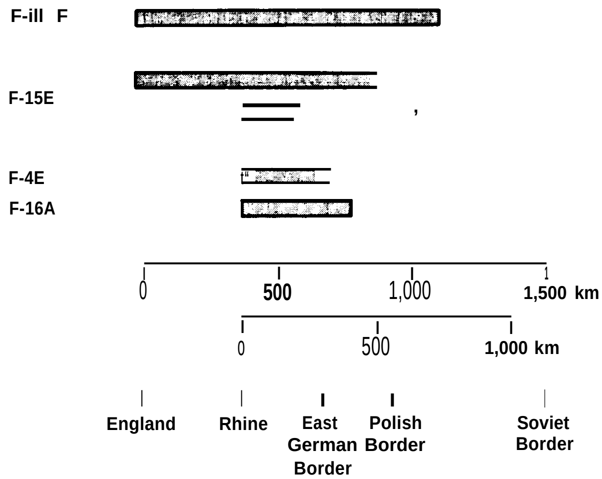
- **Targeting equipment: In** order to locate and attack targets day and night and in all weather, aircraft require aids such as high-resolution ground-mapping radar and forward-looking infrared (FLIR, which is used for precise targeting close-in; the LANTIRN targeting pod, to be acquired for the F-16 and F-15E, contains a FLIR along with electronics for controlling precision-guided bombs).
- **Crew size:** Flying an aircraft in an extremely hostile environment and operating modern precision-guided ground-attack weapons are both demanding jobs; a two-man crew permits one member to give full attention to each task.
- **Low-altitude flight:** Because of the dangers of being spotted by enemy radar and being shot down by ground-based air defenses, aircraft penetrating enemy territory may fly very low–200 feet or so;[3] not all combat aircraft are equipped with the terrain-following radar or infrared navigation equipment needed to maintain these low altitudes safely at night or in bad weather. (The LANTIRN navigation pod provides both.)

¹The F.15E will retain the F-1 5's air-to-air combat capabilities, and in fact may be called on early in a conflict to carry out air superiority missions, but is built primarily for ground attack.

²This report deals with U.S. systems. Airplanes that are in the inventories of our Allies, but not our own, are not discussed, Principal among these is the Tornado aircraft, currently in production. The ground attack versions being procured by the Germans carries the MW-1 submunition dispenser, aspects of which are discussed in this appendix.

³This doctrine is being reconsidered, however; some analyses suggest that medium-altitude flight may prove safer, in some cases.

Figure A-2.—Combat Radii of Unrefueled U.S. Ground-Attack Aircraft



Assumptions: HI-LO-LO-HI profile from England; LO-LO-LO from Germany
LO flight at 480 knots and 200 feet
4,000 lb of ground-attack ordinance plus self-defense weapons*

● The assumed loads listed below were provided by the Air Force to place the range comparisons on a common basis; they are not meant to represent the preferred ordinance for actually attacking follow-on forces.

F-1 11 F: ECM Pod, PAVE TACK
2 x AIM-9
2 *x* Mk-84

F-4E: ECM Pod; 2 external fuel tanks
2 x AI M-7
2 *x* Mk-84

F-16A: ECM Pod; 2 external fuel tanks
2 x AIM-9
2 *x* Mk-84

F-15E: LANTIRN nav + trgt pods; 2 conformal, 3 external fuel tanks
2 x AIM-9; 2 x AIM-20 (AMRAAM)
2 *x* Mk-84

- **Availability:** The multi-purpose fighters will be largely committed to fighting the air superiority battle for at least the first few days of a war in Europe, according to Air Force analyses; committing aircraft to FOFA missions would reduce the Air Force's ability to gain or maintain air superiority. In addition, some of the ground-attack fighter/bombers (particularly F-1 11s and designated F-4s) probably would be held on alert for tactical nuclear missions and would be unavailable for conventional air interdiction.

Because of the long development time for new aircraft, NATO is likely to continue well into the 1990s with current equipment and the equipment entering the inventory in the next few years. (See table A-1.)

When flying directly over the target, a manned aircraft has the advantage of placing a human observer in a position to adjust his plans to the immediate situation on the ground. On the other hand, the accuracy with which direct-overflight munitions—bombs, or dispensers holding submunitions—can be delivered to targets can be relatively low. For a dive-bombing attack, the accuracy is very good. For a "toss" delivery, in which the aircraft remains several kilometers away from the target and releases the bomb during a climb—in effect lobbing the bomb to the target—accuracy is lower. In both cases, too, the aircraft may be very exposed to ground-based air defenses.

Table A.1 .—Ground-Attack Aircraft Characteristics

F-111
loc[a]: 1988
Crew: *2*
Take-off weight: 42,000 kg
Targeting: ground-mapping radar
FLIR on F-11IFs with PAVE TACK pod
Night/all-weather: yes

F-15E
IOC: 1989
Crew: 2
Take-Off weight: 37,000 kg
Targeting: ground-mapping radar; FLIR[b] with LANTIRN[c] targeting pod
Night/all-weather: yes, with LANTRIN nav pod

F-16
IOC: 1979
Crew: 1
Take-off weight: 15,000 kg
Targeting: visual; LANTIRN will add FLIR
Night/all-weather: at present, no; LANTIRN nav pod could provide capability

F-4
IOC: 1961
Crew: 2
Take-off weight: 28,000 kg
Targeting: visual; PAVE TACK on F-4Es add FLIR
Night/all-weather: no

aIoe—Inltlal operational capability.
[b]FLIR—forward-looking infrared.
[c]LANTIRN—lowaltitude navigation targeting infrared night.

SOURCES: *Jane's All the World's Aircraft* 7985-&3 (London: Jane's Publishing Co. Ltd., 1985). *Nuclear Weapons Databook, Volume I* (Cambridge, MA: Ballinger Publishing Co., 1984). "The F-15E" *International Defense Review,* August 1985.

The standard bombs in the Air Force inventory are the 500-lb Mk-82 and 2,000-lb Mk-84 free-fall, general-purpose bombs. A variety of dispensers have been developed to hold submunitions; most are released like bombs, but are fuzed to break open after a set interval or when a set altitude is reached, scattering the submunitions.

Close-Range Air-to-Ground Missiles

By adding a guidance system and controllable tail fins to free-fall bombs or submunition dispensers, accuracy has been greatly improved. Wings, which permit the bomb to glide aerodynamically, or a small rocket motor give these missiles a modest range that permit the aircraft to remain several kilometers away from the target. The guidance concept of these missiles, however, requires that the target be in sight at the time that they are launched.

Two basic approaches to guidance are employed: laser-spot designation and autonomous TV-tracking. In the former, a laser beam is aimed at the target either by the attack aircraft or a second, "buddy" aircraft, and the missile homes in on the reflected laser light; in the latter, a TV or imaging-infrared camera is mounted on the nose of the missile, the pilot or weapons officer lines up the target in cross-hairs on a TV screen, and the missile then locks on to that point and guides itself in.

Paveway.–The Paveway series of laser-guided bombs consists of kits that are attached to conventional Mk-82 and Mk-84 bombs. The laser "designator," which produces a coded beam that matches a code fed into the bomb's electronics before take-off, is carried in a pod mounted either on the attack aircraft or on a second aircraft which could remain at a safe distance from the target while the attack aircraft flies in and releases the bomb. The current designator pod, PAVE TACK, has a forward-looking infrared (FLIR) camera which sends a picture of the ground ahead to the cockpit; the weapons officer uses a joystick to line up the target in cross-hairs and must keep it there manually until the bomb impacts. It is currently deployed on F-4 and F-1 11 aircraft, which have two-man crews. A new targeting pod, LANTIRN,[4] is being developed for the F-16 and F-1 SE; once a target is initially selected, LANTIRN can be locked on, automatically keeping the laser designator pointing at it, and freeing the pilot or weapons officer to perform other tasks.

The older Paveway IIs in the inventory cannot be dropped from low altitude because of their small airfoil, a fact that severely hinders their usefulness in the face of antiaircraft defenses. A new version, Paveway III, also known as the Low-Level Laser-Guided Bomb, has an improved guidance system. The Air Force decided in spring 1985 to cancel its planned procurement of paveway III because of rising costs, however. The 5,000 Mk-84 versions (known as the GBU-24) purchased with fiscal year 1985 funds will be delivered by 1987; some 500 have been delivered so far (along with 200 of the Mk-82 versions, known as GBU-22).

Maverick.–The Air Force has in operation with F-4, F-1 11, and F-1 6 aircraft a TV-guided antiarmor missile, the Maverick AGM-65B. In operation, the pilot can slew the TV camera located on the nose of the bomb to line up the target in cross-hairs on a TV display in the cockpit; the Maverick is then launched and flies autonomously to the indicated target. It is propelled by a small solid-fuel rocket motor. Approximately 30,000 TV Mavericks have been produced.

A new version, now in production (the AGM-65 D), substitutes an imaging infrared **(IIR)** seeker for the TV. Its operation is similar to that of the TV version; but in addition it can be used at night and under low visibility, and it roughly doubles the range at which targets can be recognized even in daylight. The IIR version also can be used in conjunction with the LANTIRN targeting pod, which simplifies the job of finding and locking onto a target. (F-16 and F-1 SE aircraft are to be equipped with the LANTIRN system, which consists of a targeting pod and a navigation pod. The navigation pod includes a terrain following radar, which allows the pilot to fly at low altitudes even at night, and a forward-looking infrared (FLIR) camera that gives the pilot a night-vision picture of the ground below.) The LANTIRN targeting pod can give the pilot a wider field-of-view picture than does the Maverick's own camera; once the pilot locates a probable target on the wide field-of-view LANTIRN display, he can switch to a higher magnification to identify it and then lock

[4]For "Low-Altitude/Navigation and Targeting Infrared System for Night."

the Maverick seeker onto it.[5] Without LANTIRN, the entire search would have to be carried out by slewing around the small field-of-view Maverick seeker, a difficult job for the pilot of a single-seat aircraft who must at the same time keep the aircraft flying at low altitude and avoid hostile fire. The Air Force Mavericks carry a 60 kg shaped-charge warhead for penetrating armored vehicles.

Short= to Medium- Range Air-to-Ground Missiles

Longer range air-to-ground delivery systems incorporate guidance systems that do not require a direct line of sight to the target at the time of launch from the aircraft. They also permit aircraft to stay out of range of the enemy's terminal air defenses (in the case of the short- to medium-range missiles in this section) or even to avoid having to penetrate enemy airspace altogether (in the case of the long-range missiles discussed below).

For the medium-range missiles in this category, the two systems used are command guidance, in which a radio data link allows the operator to steer the missile throughout its flight; and inertial guidance, in which the missile is programmed before launch with the relative geographic coordinates of the target and then flies out on its own. Ranges of tens of kilometers are characteristic of these systems. A third basic guidance system, which allows the missile to recognize the target automatically and home in on it, is in laboratory stage of development, and may be incorporated into the Autonomous Guided Bomb, discussed below.

GBU-15/AGM-130.—The Air Force is now acquiring the GBU-15, a command-guided glide-bomb built around a 2,000-lb Mk-84 warhead. A TV camera mounted on the nose transmits a picture back to the cockpit during its flight. The weapons officer uses a joystick to steer the GBU-15, making course corrections as needed; once the target is well in view, it can be lined up in cross hairs and the guidance system locked on to automatically guide the final approach. (If the target is in sight before launch, the target can be locked on from the start.) As with the Paveway, control can be handled either by a weapons officer in the attack aircraft or from a second aircraft that remains farther from the target; the radio link of the GBU-15, however, allows this buddy aircraft to be much farther away, provided it maintains a direct line of sight to the bomb's flight path. The aircraft controlling the GBU-15–currently F-4E, F-1 11 F, and, when it arrives, the F-15E–must carry a 200-kg data link pod.

Since production began in 1980, 1,600 have been purchased and 700 delivered. The unit cost has fallen from $194,000 in 1980 to $128,000 in 1985. An imaging infrared version, to allow night and poor-weather operation, is now in initial low-level production; full production is scheduled to begin in 1988. The seeker was adapted from the imaging-infrared Maverick.

The range of theGBU-15 can be roughly doubled by adding a small rocket motor;[6] such a system, designated AGM-130, is now in full-scale development, with initial production of one version scheduled for fiscal year 1987. That version, the AGM-130A, carries a 2,000-lb Mk-84 bomb. The AGM-130B, which would instead carry a submunition dispenser, is not currently funded. (Although only one submunition load, designed for airfield attack, was being planned for the dispenser version, in principle other submunitions could be used as well.) Current plans also call for incorporating the improved 2,000-lb bomb, designed to penetrate hardened targets, in fiscal year 1988 in a third version of the AGM-130. The Air Force is currently planning to begin work late in fiscal year 1986 on a new data link that will be more resistant to jamming than the present model; the first improved models would be produced in fiscal year 1990.[7]

‘An automatic target recognition (ATR) system is being developed for possible installation on advanced versions of the targeting pod. Developmental versions of this system have been tested.

[6]The actual range improvement depends on launch altitude, with the greatest relative improvement at low-level release.

[7]Several other concepts for improving the utility of the GBU-15/AGM-1 30 have been suggested. Inertial guidance could, for example, allow the pilot to release the bomb while flying obliquely to the target; it would also reduce the workload on the weapons officer, making it feasible to control more than one bomb at a time, switching from one to another only as each one reached the final approach to the target. The data link is already configured to handle four channels, thus allowing four bombs to be in flight at once; studies by Rockwell, the prime contractor for theGBU-15 and AGM-130, suggest that the workload of fourGBU-15s with inertial guidance is comparable to that of one standard GBU-15.

Inertially Aided Munitions.–A demonstration program is in progress at the Air Force Armament Laboratory to incorporate a low-cost inertial navigation system into a guided Mk-82 bomb (the concept is equally applicable to the Mk-84). The coordinates of a fixed target would be entered before take-off; Global Positioning System data would provide the position of the aircraft at the time the bomb is released. Because the time of flight of the bomb is so short (on the order of a minute), drift of the inertial system is not a serious problem, and a low-quality system can be tolerated. Inertial navigation would allow the bomb to be released at a location preselected to be safe from antiaircraft defenses; the target need not be in view; and a second crew member is not needed to control the bomb to the target. When released at a distance from the target, the accuracy would be better than that attained in conventional dive-bombing with free-fall bombs. The 2-year demonstration program started in fiscal year 1986; a further 2 to 3 years would be needed for full-scale development. The cost objective is $10,000 each.

LOCPOD,SRSOM.–The United States, Italy, Spain, and Canada are jointly funding a feasibility study for a low-cost, probably inertially guided, powered submunition dispenser. The principal targets would be airfields; a range of 15 to 30 km is contemplated. A feasibility study for a similar dispenser that would carry antiarmor submunitions for attacking armored combat vehicles may begin in late 1986; the United States, Britain, and Germany are now involved and other NATO members have expressed interest. Discussions are under way to fold both programs together into a single NATO cooperative development program for a "modular standoff weapon. "

Autonomous Guided Bomb.–For attacking some high-value fixed targets, such as bridges, the accuracy of a pure inertial system is insufficient. One way to combine the autonomy of the inertially aided munitions with the precision of the command-guided bombs is to equip the bomb with an automatic capability to recognize the target and guide itself in to a precise impact point. The Air Force Armament Lab is cataloging imaging infrared features of "generic" targets and developing algorithms to automatically recognize key features. An early version, of which the Air Force is planning to begin full-scale development in 1988, would be programmed before take-off with information about the target and its location relative to a preplanned release point. It would probably be built around the Low-Level Laser-Guided Bomb or the AGM-130. A research program is also exploring the application of automatic target recognition to millimeter-wave sensors for the GBU-15 and Maverick.

Long- Range Air-to-Ground Missiles

The Air Force has for several years been interested in a longer range (several hundred kilometer), conventionally armed, air-launched cruise missile, primarily for airfield attack. At these ranges, inertial guidance alone is no longer sufficient: the accumulated drift in even very expensive inertial systems is simply too greats Periodically correcting the inertial guidance system by comparing the missile's actual location—as measured by sensors which scan the terrain below—against prestored maps can improve the accuracy; this is the technique (known as TERCOM, for terrain comparison) used in nuclear-armed cruise missiles. But accuracy is still not sufficient for conventionally armed missiles, which—at least for hard targets such as bridges and reinforced-concrete buildings—must get to within a matter of a meter.

Even correcting the inertial system with data from the Global Positioning System satellites may not solve the problem if the exact location of such fixed targets is not known with sufficient accuracy. Thus inertial guidance would likely be applicable only to mid-course guidance of a conventional, long-range cruise missile.

Terminal guidance, involving a sensor that looks at the actual target, would be needed to fine-tune the missile's course on the final ap-

[8]The high-accuracy mechanical gyroscopes used in commercial aircraft inertial navigation systems typically have a position error that increases at a rate of 0.s km per hour; ring-laser gyroscopes which are far less expensive and more compact, have a higher drift rate. (See *Proceedings of the IEEE,* October 1983, 71, pp. 1121-1232.) A cruise missile flying 600 km at high subsonic speeds would, if it relied on inertial navigation alone, wind up at least several hundred meters off target. Fiber optic gyros, currently under development, promise to be cheaper and more accurate than ring-laser gyros (see *IEEE Spectrum,* March 1986).

preach. The two basic approaches are scene matching, which compares an optical or imaging infrared image with a stored picture of the actual target; and automatic target recognition, which combines a sensor (laser radar, TV, imaging infrared) with a processor that recognizes the key features of generic types of targets. The former is already in use in the conventionally armed ground- and sea-launched Tomahawk cruise missile and the reentry vehicle of the Pershing II ballistic missile; the latter is in the laboratory stage.

JTACMS.–An outgrowth of the **now-defunct** MRASM medium-range air-to-surface missile program, JTACMS is a joint Air Force-Army effort to develop a new conventionally armed missile.

LRSOM.–The United States, Britain, and Germany are working jointly on a feasibility study for a conventional cruise missile known as the NATO Long Range Standoff Missile (LRSOM); the project began in April 1985. No hardware is being built yet, however. The main target for such a missile would be heavily defended airfields, and the missile would be designed chiefly to carry runway cratering submunitions and mines. The concept could in principle be adapted to other missions, however. Some form of terminal guidance would be necessary in either case. The missile would be launched from an aircraft (although ground launching might be an option) and have a range of up to 600 km (the limit set by the SALT II agreement on cruise missiles launched from aircraft other than strategic bombers).

Ground-Launched Missiles, Rockets, Artillery

Ground-launched weapons that might otherwise be suitable for follow-on forces attack have, until very recently, had little capability of reaching much beyond the range of conventional artillery—about 30 km. Although some longer range tactical surface-to-surface ballistic missiles (currently, Lance) have had a nominal capability to carry conventional explosives, their essential purpose lies in the tactical nuclear mission. Proposals have from time to time been made to adapt intermediate-range ballistic missiles to conventional missions, for example using the first stage of the Pershing Ia or II for airfield attack, g but there are no actual programs at this time; similarly, the nuclear-armed ground-launched Tomahawk cruise missile could be armed with a conventional warhead (as is in fact done in two ship-launched versions of the Tomahawk), though there are no plans to do so at present.

The Army's decision in December 1985 to proceed with full-scale development of a new conventionally armed ballistic missile known as ATACMS will however change this picture significantly. Extended-range artillery, if eventually combined with guidance systems or smart submunitions, could also provide some follow-on forces attack capabilities. Smart submunitions and guidance systems are currently being incorporated into conventional artillery and rockets, with some application to very short-range FOFA missions.

MLRS.–The multiple launch rocket system consists of a 25-ton tracked vehicle that can launch 12 rockets without reloading. Its chief role is to generate the rapid surge of artillery fire needed to counter enemy artillery. A new warhead, containing smart submunitions, is being developed to give the MLRS rockets an antiarmor capability.

The United States has acquired 250 launchers to date; current plans call for a total procurement of 348 by 1988. An additional 143 launchers would be procured to handle the extra assignment of the ATACMS missile. The British, French, Germans, and Italians also plan to acquire MLRS launchers.

ATACMS.–Originally a part of the joint Army-Air Force JTACMS program, ATACMS split off in June 1984 when the Army decided to proceed at once with development of a ballistic missile that could be fired from existing MLRS launchers. Unlike the Assault Breaker missile from which it is descended, ATACMS will not have the capability to receive target course corrections while in flight; coordinates will be fed into the system just before launch. In-flight updates could allow the missile to engage targets that would other-

'strengthening Conventional Deterrence in Europe ESECS II **(Boulder, CO: Westvievv Press, 1985), pp. 55-62.**

wise have moved out of the missile warhead's kill radius during the 3-minute flight time, and that capability might be added in the future as a block improvement.

Although the accuracy of ATACMS is to be considerably better than that of Lance, it still will not have the terminal guidance that would be needed to score a precise hit on a point target. Warheads being developed for ATACMS, discussed below, are thus designed to disperse a large number of submunitions over a wide target area.

The existing MLRS launchers, which the U.S. Army and other NATO armies have already begun to acquire, will be able to handle the ATACMS without modification. The ATACMS will be packaged in canisters (one ATACMS per canister) identical in outward appearances to the MLRS canisters (containing six MLRS rockets); all U.S. MLRS batteries will be equipped with both. Thus the higher value and more threatening ATACMS will be dispersed among a larger number of MLRS rounds, making it difficult for the enemy to single out the smaller number of ATACMS for selective attack.

Munitions for ATACMS are discussed below; they are the APAM cluster warhead now used on conventional Lance, a smart antiarmor submunition (possibly an I R-Terminally Guided Submunition), and possibly a wide-area smart submunition for attacking surface-to-surface missile units.

Lance.–Development work on Lance began in 1962; it was deployed in 1976. Although a conventional warhead is deployed, the principal role of Lance is nuclear. It has a range of 5 to 125 km. Lance, which is fired from its own mobile launcher, will continue to have the nuclear role after ATACMS is deployed.

Extended-Range Artillery .-A rocket-assisted artillery shell is already in the Army's inventory; it has a maximum range of approximately 40 km. The Army Armament Research and Development Center and DARPA are also supporting research on solid-fuel ram jet rounds for 155 mm and 8 inch artillery, which may be able to extend the range to 60 to 80 km. A generic problem with all efforts to add propulsion to artillery rounds is that less and less space is available for the warhead and for a guidance system, which starts to become a necessity at longer ranges as the accuracy of a purely ballistic round degrades; or, conversely, that the round grows larger and larger.

Guided Artillery .-The Army is now acquiring a "smart" 155 mm artillery shell known as Copperhead that homes in on a target illuminated by a laser designator. Although Copperhead (also known asM712) is a short-range weapon in terms of follow-on forces attack scenarios (16 km) and requires a forward-observer (or a remotely piloted vehicle) to handle the laser designator, the principles involved in Copperhead could be extended to longer ranges if it proves feasible to incorporate such guidance systems into rocket-assisted or ramjet-powered rounds. A new sensor is being developed for Copperhead (Copperhead II) that would allow the projectile to home in on the target autonomously. (The sensor is a two-color IR detector that looks for the characteristic "signature" of a tank. It is being developed in a joint project that will also have applications to the terminally guided submunition (TGSM) being developed for the ATACMS missile, discussed below.) The cost of Copperhead is now $35,000 per round.

EM Guns.–Much further in the future are electromagnetic guns, or "rail guns, " that would achieve greater ranges through an entirely new propulsion technology. Electric generators, perhaps powered by diesel fuel, would provide the propulsion energy now provided by an explosive charge. In principle, an electromagnetic gun would be easier to resupply (diesel fuel is easier to move than the conventional artillery propellant) and would have a longer range; in addition, an EM gun would not subject the projectile to the very high initial acceleration of artillery that requires electronics systems incorporated into artillery projectiles (guidance and smart submunitions) to be engineered to withstand that shock. Even optimistic projections, however, do not place initial production of an EM gun before the first decade of the next century.

Munitions

The representative approaches to carrying out follow-on forces attacks described in the summary identified three broad classes of targets: armored maneuver units; "hard" fixed targets, such as bridges and heavily reinforced concrete command posts; and "soft" area targets, including movable command posts, air defenses, surface-to-surface missile units, and other lightly armored or unarmored vehicles within the maneuver units.

Combat Vehicles

The principal targets for follow-on forces attack are the follow-on forces themselves, which are made up of large numbers of armored combat vehicles (e.g., tanks, personnel carriers, infantry fighting vehicles) along with about twice as many trucks and other light vehicles. They may be on trains moving across Poland, or, closer to the battle area, moving along roads either on transporter trucks or under their own power; at intervals they may also be stopped, either pulled off along roads or arrayed in assembly areas.

The fact that they are moving much of the time, however, and the fact that at least the tanks (less so the other armored vehicles) are heavily protected against conventional high explosive munitions, imposes some special requirements on he munition-delivery system package. During the i me that elapses from the moment a target is located, to the time that that intelligence can be processed, an order to attack issued, and a delivery system finally arrives over the target area, he target may well have moved. Thus either the nunition must have a large kill radius to compensate for the uncertainty in the target's final position, or the delivery system must have some utonomous capability—either a human or a sophisticated automatic target recognition system—ɔ look for the target and adjust its course accordingly.

The increasingly heavy armor on Soviet tanks means that a virtual direct hit is required to cause ny damage—a 500-lb Mk-82 bomb would have ı land literally within a meter of a tank to be effective. One solution to this problem is the use of "smart" precision guidance on the delivery system, as is done in the Maverick air-to-ground missile. The solutions that apply directly to munitions are of two general types:

1. cluster bombs, which blanket the target area with many small, unguided submunitions; and
2. smart submunitions, which incorporate guidance or sensor electronics into the submunitions themselves.

By spreading the kill mechanism over a wide area, both of these approaches increase the effective kill radius of the weapon as compared to a unitary warhead of equivalent weight; they also permit several targets to be killed with a single weapon. In the case of air-delivered munitions, this means the pilot need only look for an array of vehicles rather than pinpointing each individual vehicle and attacking it separately, one target per pass; for both air and ground delivery, it reduces the delivery accuracy needed.

The use of smaller submunitions in the place of a single 500 lb or 2,000 lb bomb in turn, however, requires the development of lethal mechanisms more sophisticated than simple high explosive blasts. The two principal technologies are the shaped charge, which focuses a relatively small explosion into a concentrated jet of gas that more readily penetrates armor (but which, conversely, has to hit the target directly to be effective); and the self-forging fragment or explosively formed penetrator, a thin, extremely high velocity metal slug that impacts (and may penetrate) the tank armor, causing fragments of armor to span off on the inside of the tank. A number of the concepts discussed below—particularly those employing explosively formed penetrators, which, as a rule, are less able to penetrate armor than shaped-charge warheads—envision attacking tanks from the top, where the armor is the thinnest.

Armored combat units can also be attacked by mines. Traditionally, mines have been considered a delaying tool; in a typical scenario they would be used to create a chokepoint where vehicles back up, forming a lucrative target for direct attack by air- or ground-delivered weapons. Recent technological developments, though, which allow mines to be emplaced remotely–either by aircraft, or by artillery or rockets—and which incorporate smart sensors and an extended area of effect into mines, may increase their effectiveness to the point where they can be considered antiarmor weapons in themselves.

All of these new antiarmor systems face continuous improvements in Soviet armor. Composite armors with spacings between layers provide significant increases in protection. Reactive armor—layers containing small explosive charges that are set off when hit by an antitank weapon —can degrade the effectiveness of modest-sized shaped charges. Other advances in armor effectiveness are likely to be made by the time many of the new antiarmor systems discussed here can be fielded.

CLUSTER BOMBS

Rockeye.– Built in the 1960s and procured in considerable quantities, the Rockeye is a 500-lb-class bomb; after release, a time fuze triggers the bomb to break apart, releasing 247 unguided antiarmor shaped-charge bomblets.

According to the Air Force, Rockeye is not effective against the newer Soviet tanks; it would, however, be effective against more lightly armored vehicles and older tanks still in the inventories of non-Soviet Warsaw Pact armies.

CEM.–The principal new Air Force cluster weapon is the Combined Effects Munition, which consists of 202 beer-can-sized bomblets in a Tactical Munitions Dispenser; the TMD is a new general-purpose, 1,000-lb-class submunition dispenser designed to be dropped from as low as 200 feet. An air bag on each bomblet causes it to descend vertically, increasing its probability of hitting the vulnerable top of an armored target. The CEM bomblets consist of a shaped charge for penetrating armor, inside a fragmenting case which produces shrapnel that can damage trucks at 20 m and aircraft or personnel at 80 m; a zirconium incendiary capable of igniting diesel fuel at a distance of 3 m is also included. Against tanks, however, it is effective only on the more lightly armored surfaces. The TMD can be adjusted to produce a pattern of bomblets on the ground ranging from roughly 100 to 300 m long. Deliveries to inventory began this year; approximately 30,000 are to be purchased by the end of fiscal year 1988; and the procurement goal is 200,000 to 300,000. The cost is approximately $20,000 per fully loaded TMD.

KB-44.–Designed for use in the MW-1 submunition dispenser, the KB-44 is a small, shaped-charge bomblet weighing half a kilogram. Tail fins stabilize its flight. A fully loaded MW-1 dispenser delivers 4,500 KB-44s. The MW-1 dispenser is carried on the German-British-Italian Tornado fighter; it remains fixed on the aircraft's underbelly and rapidly ejects the submunitions in sequence when the aircraft passes over the target. (It thus requires the aircraft to fly directly over the target; a toss delivery is not possible.) The MW-1 is too long to fit on other aircraft; Germany is developing another version—the Modular Dispenser System–to be compatible with all NATO aircraft.

DPICM.–The current warhead for the MLRS rocket launcher—so-called MLRS phase I—contains 644 dual-purpose improved conventional munitions (DPICM) per round which are scattered over a 100-meter-radius circle on the ground. Each DPICM contains a small shaped charge surrounded by a fragmenting case, so that it is effective against both light armor and materiel and personnel. (The DPICMs are slightly smaller than the CEM bomblets.) The United States has so far acquired 14,000 MLRS rockets with DPICM warheads; plans call for a total inventory of 362,000.

SMART SUBMUNITIONS

Smart submunitions offer in principle several advantages over either conventional bombs, cluster bombs, or precision-guided bombs. The two major types of smart submunitions, terminally guided submunitions and sensor-fuzed submunitions, both operate by searching out an area on the ground for a tank or other armored vehicle and accurately delivering a projectile to it. (The terminally guided submunitions fly directly into the target, sometimes described as "hit-to-kill"; the sensor-fuzed submunitions shoot an explosively formed penetrating rod into the target from a distance of 100 m or so, described as "shoot-to-kill.") Because they are small, several submunitions can be packed in the space of a single conventional bomb; because they can search out areas 100 to several hundred meters across, they do not have to be precisely delivered by aircraft or surface-to-surface weapons; and because they are able to detect and precisely locate the target, autonomously, they can achieve a greater number of kills per pass.

Two sensor technologies have been used to date in smart submunition designs: **infrared** detectors, which sense heat—typically coming from the tank's engine compartment; and **millimeter wave** detectors, which can either be passive—which sense a different wavelength of heat radiation than do infrared detectors, but with poorer resolution—or active, which is a form of radar, with better resolution than typical longer wavelength radars.

How well these sensors can detect tanks under a variety of conditions, including the presence of countermeasures that the Soviets might deploy, is currently being tested in a joint Army-Air Force program. The performance of the warheads is also being tested. The results of these tests are expected to influence strongly the course of development of new sensors and the choice of submunitions for new weapons systems.

The major issues that will determine the choice between a terminally guided submunition (TGSM) and a sensor-fuzed weapon in any given application are:

- cost (sensor-fuzed weapons are cheaper by a factor of 5 to 1 O);
- "footprint' '-the area on the ground searched (TGSMS cover an area some 50 times greater); and
- lethality (TGSMs, which use a shaped-charge explosive, have a greater penetration than the explosively formed penetrators).

TGSM.–The terminally guided submunition incorporates some of the automatic target recognition and guidance concepts discussed in connection with cruise missiles; however, because it is specifically an antitank weapon and as such has a limited target set to search for, the technology is simpler—it is not so much target recognition as target detection. In the typical deployment, TGSMs would be released from a missile, rocket, artillery shell, or aircraft and, after falling to an altitude of several hundred meters, would begin to glide at a steady altitude with their seekers scanning back and forth across a track on the ground, ***500*** to 1,000 m wide. The length of the search "footprint" depends on the speed and altitude at which the TGSMs are released; it might typically be several kilometers. When the seeker detects an object on the ground that matches the characteristics of a tank, it sends a signal to the guidance system to steer toward it by adjusting its control fins. A shaped-charge warhead, containing a few kilograms of explosive, detonates on impact.

A TGSM was developed for the Assault Breaker demonstration project. Closest to actual deployment is a millimeter-wave TGSM now being developed for the MLRS rocket (usually referred to as MLRS phase Ill, or the MLRS Terminally Guided Warhead (TGW)). The project is a French-German-British-United States collaboration, with 40 percent of the funding coming from the United States and the remainder split equally among the other three partners. Low-level initial production is scheduled to begin in late fiscal year 1989 with full production by fiscal year 1992. Current plans call for six TGSMs to be packed into each MLRS rocket, though there are some doubts that it will prove feasible to keep the size of the TGSMs under the 26-inch length limit that this goal prescribes; three larger TGSMs (which would on the other hand have larger warheads) might be used instead.

The U.S. Army has favored an infrared sensor for the TGSM, and is planning a l-year program, beginning in June 1986, to develop a candidate two-color IR seeker for use in an ATACMS missile (known as ATACMS Block II; Block 1 is the conventional APAM warhead discussed below). A decision to proceed with full-scale development of the ATACMS Block I I would come in fiscal year 1989. The seeker would be gun-hardened—that is, capable of withstanding the shock of being fired from mortar or artillery-so that it could also be used in a guided artillery shell such as Copperhead II.

The Air Force is also supporting an analysis project that is examining the utility of air-launching TGSMs from a Tactical Munitions Dispenser or a dispenser version of the air-to-ground missile, AGM-130.

Skeet, Search and Destroy Armor (SADARM). –Unlike the TGSMs, the sensor-fuzed weapons do not fly into the target; they descend in a fixed vertical or parabolic free-fall trajectory, scanning a much narrower piece of ground for a target, and fire a self-forging penetrator when they detect a target. Because of the narrower search area, much simpler infrared (IR) or millimeter wave detectors can be used (they are referred to as "sensors" to distinguish them from the much more sophisticated "seekers" employed in TGSMs) and the expensive guidance systems of the TGSMs which are needed to translate the data collected by the seeker into control signals for the steerable tail fins are eliminated altogether. (As a rule of thumb, ***70*** or ***80*** percent of any guided missile's cost is in the guidance systems; cost of one SADARM is estimated to be several thousand dollars as compared to $20,000 to $50,000 for a TGSM.)

The Air Force's version (known by the Air Force as simply the Sensor-Fuzed Weapon or SFW or by the contractor's name for the submunition, "Skeet") is designed to be dispensed from a Tactical Munitions Dispenser. All of the sensor-fuzed weapons must spin while descending so that the fixed sensor or sensors on the submunition can scan out an area on the ground. The Air Force SFW employs a complex deployment sequence to achieve this spin and to allow deployment at low altitudes; the Skeet are ejected, spinning, in a 100-m long parabolic trajectory. Each TMD contains 40 Skeets; all together they cover an area on the ground, with the theoretical possibility of hitting as many as 40 vehicles in that area. The SFW submunitions employ a two-color IR sensor, which "looks" for the engine compartment of a tank.[10] In a test conducted at Sandia, New Mexico in September 1985, in which four Skeets were mechanically tossed over tanks, all four hit the targets; three of the four hits were considered to have been "kills" that would have put the tanks out of action. The Air Force recently decided to proceed with a $57 million full-scale development program. Production could begin in fiscal year 1989; the procurement objective is 14,000 TMD-loads at a total cost of approximately $2 billion.

The Army's sensor-fuzed submunition program, known as SADARM (for "Sense and Destroy Armor"), is about to begin engineering development of submunitions for 155 mm artillery and MLRS rockets. Both will use simple IR and millimeter wave sensors. In each case, the SADARMs are deployed from the shell on a parachute that is designed to rotate as it drops, causing the submunition to spin around the vertical axis. The sensor, which looks down at a 30-degree angle from the vertical, thus scans out a collapsing spiral on the ground, covering a circle with a diameter of roughly 150 m. The accuracy of the shot is determined in effect by the accuracy of the sensor.

A SADARM has already been developed for the larger 8-inch artillery shell, and was successfully demonstrated in a test-firing in April 1985, in which a shell containing one SADARM submunition was shot 10 km and the SADARM deployed and hit its target. The Army has decided not to proceed with production of the 8-inch version, however. The MLRS effort began in the second-quarter of fiscal year 1986, with the 155 mm to follow in fiscal year 1987; both will be gun-hardened and the goal is that they will have 70 percent of parts in common. Initial low-level production would begin 2½ years after the start of the development work in each case; the first ones would be fielded in 4½ years. The MLRS SADARM can be of the same diameter as the SADARM developed for the 8-inch gun, and can thus be available sooner than the 155 mm version; the major challenge is reducing the cost. The 155 mm version poses a greater technical challenge, as the 8-inch version (which has an outer diameter of 6.9 inches) will have to be shrunk to a 5.9 inches outer diameter. (The smaller size makes packaging the sensors more difficult; it also requires using a smaller penetrator, which will be less lethal.) An MLRS rocket could carry six SADARMS, which together would cover an area of roughly 400 m by 400 m on the ground.

[10] The original version, which used only a single-color IR Sensor, suffered from a problem known as "fratricide": the flash of one Skeet firing would be picked up by the IR sensors of all of the other Skeet in the area, triggering them to go off as well. Two-color sensors are able to estimate the target's temperature and thus distinguish a warm tank from the flash of other Skeet firing and from flares which might be used as decoys.

MINES

Two major advances in technology have occurred that may make mines attractive candidates for follow-on forces attack missions. First, methods for dispensing mines remotely—from artillery, rockets, or aircraft-have been developed; and second, the lethality of mines against armored targets has been greatly increased. The usual concept of employing mines calls for antipersonnel mines to be scattered along with the antiarmor mines in order to make clearing the minefield with infantry as difficult as possible.

FASCAM.–The Army and Air Force have developed and are now acquiring two basic types of remotely deliverable mines—antitank and antipersonnel–known generically as FASCAM (for "family of scatterable mines"). The Air Force version, known as GATOR, consists of a 1,000-lb-class tactical munitions dispenser containing 72 antitank mines and 22 antipersonnel mines. The mines land over a 200-foot by 300 to 400 foot area on the ground when the TMD is dropped at an altitude of 200 feet. The TMD can be carried on all NATO aircraft. The Army versions are delivered in a 155-mm artillery shell, carrying 36 antipersonnel mines (known as ADAM) or 9 antitank mines (RAAM) per shell. Helicopter, truck, and hand emplaced versions are also being acquired.

Although there are differences in the Air Force and various Army versions, most of the components of the mines are shared. The antitank mine has a magnetic sensor that is activated when a tank passes directly over; an explosive charge is then set off which forms a steel plate at the top of the mine into a high-speed slug which penetrates the lightly armored belly of the tank. The antipersonnel version unreels long (20 feet for ADAM, 40 feet for GATOR) triplines on descent; a large fragmentation grenade is set off when the triplines are disturbed. Both mines self-destruct after a preset time. The Air Force began purchasing GATORs in 1983, at a cost of $55,000 per GATOR; approximately 1,500 are now in the inventory. Both ADAM and RAAM are currently in production; approximate costs are $4,000 per ADAM shell and $5,000 per RAAM shell.

The Army Armament Research and Development Center is examining new sensors, including acoustic, seismic, infrared, and optical sensors that may be more resistant to countermeasures; remote control of mines (which could for example allow mines to be emplaced and activated or cleared by radio command at a later time); and new warheads.

MIFF.–The West Germans have developed a similar air-delivered antitank mine, MIFF. At present, it can be delivered only by the German-British-Italian Tornado aircraft equipped with the l0,000-lb MW-1 submunition dispenser; 896 MIFFs are spread over a large area, 500 m wide by 180 to 2,500 m long. The MIFF employs seismic and magnetic sensors and a shaped charge explosive,

AT-2.—West Germany is developing a scatterable mine to be carried in MLRS rockets; the program is designated MLRS Phase II. The mines–28 per rocket—descend on a parachute and automatically right themselves after landing. A wire antenna which mechanically senses a tank passing over sets off a shaped-charge explosive. Although the United States is committed to assisting the research effort by developing the packaging needed to integrate the mine into the rocket, there is little interest in the Army to purchase the mine when full-scale production begins in 1988. The U.S. Army Training and Doctrine Command is, however, reviewing the need for an MLRS-deliverable mine. West Germany and Italy are committed to purchasing the AT-2; Britain and France have expressed interest.

ERAM.-The Air Force has developed a prototype "smart" mine that is indicative of the direction in which mine technology is heading: ability to control a wide area (and thus the ability to command a road from a concealed position to one side), to discriminate between tanks and lower value targets, and to attack the lightly armored areas of the tank (in this case the top). The ERAM (extended-range antiarmor mine) consists of nine mines (BLU-101 submunitions in the Air Force's designation) in a tactical munitions dispenser, The TMD is dropped, and the mines dispensed sequentially, falling by parachute over a ground pattern typically 200 to 300 m long.

When a seismic sensor picks up a tank's vibration, the mine's main electronics are switched on and three acoustic sensors begin to track the tank's movement; the seismic and acoustic sensors together can determine the location of the tank, its speed and direction, and can distinguish between tanks and other vehicles. When the tank reaches its closest approach to the mine, the mine rotates and fires a Skeet submunition up and over the tank. The submunition, which itself contains an infrared sensor (a more complete description appears above in the section on smart submunitions) flies in a 200-foot-long, 50-foot-high arc, searching for the precise location of the tank. When the IR sensor detects the tank (it looks particularly for the hottest spot on the tank, namely the lightly protected engine compartment), the Skeet fires a self-forging fragment directly down onto the top of the tank. The mine thus covers a range of 200 feet in all directions; it is equipped with two Skeets, as well as three fragmentation grenades that are lobbed out when the detectors sense the approach of personnel,

After final tests of a prototype, the Air Force decided not to proceed with full-scale development in fiscal year 1987 as originally planned. The estimated cost is $75,000 per TMD-load. The Army Armament Research and Development Command is exploring an almost identical concept for development by the Army,

Hardened Fixed Targets

Bridges and tunnels, which may be important targets in the effort to halt the movement of follow-on forces forward, are representative of a class of hard, fixed targets. Their location is known in advance; but to destroy them requires a very precise hit with high explosives. Taking out a bridge, for example, may require hitting a support member to within a meter or less. The hardness of these targets poses other problems for conventional munitions as well: a bomb may actually bounce off, it may fail to penetrate far enough into the target before detonating, or the fuzes may be damaged on impact.

Two general approaches to munitions are being pursued to deal with these targets: bomb cases can be hardened to increase their penetration; or rocket motors can be added to accelerate the projectile through the fortifications ("kinetic energy penetration"). Although most of the existing boosted kinetic energy penetrators have been developed for cratering runways, the basic concepts are applicable to penetration of other hardened targets.

I-2000/HAVE VOID.–The conventional 2,000- Ib Mk-84 bomb is capable of penetrating 3½ feet of concrete if it strikes it perpendicularly; the penetration drops off sharply as the angle of impact decreases, to the point where the bombs may actually bounce off. In addition, penetration of hard targets sometimes damages the fuze of the bomb, which then fails to detonate. The Air Force has initiated a quick program to develop an improved Mk-84 to be used with a Paveway II laser guidance kit on the F-4E fighter. A forged steel case will replace the rolled and machined steel of the Mk-84; and the nose and aft fuzes of the Mk-84 will be replaced with a single aft fuze. Penetration of 6 feet of concrete with a perpendicular impact and 3 feet at a 45-degree angle is expected. The fuze is factory set to detonate the bomb at a fixed time interval after impact to allow the bomb to penetrate. A production contract was awarded in June 1985 and a limited buy of 1,300 is planned. Cost is $14,000 per bomb; the Paveway II guidance unit adds another $15,000.

1-2000 P31.–A longer term program, with production planned to begin in fiscal year 1987, will adapt the initial 1-2000 bombs from the HAVE VOID program for use with the GBU-15, Paveway III, or as an unguided bomb; it will preserve the mechanical characteristics of the Mk-84 and will be compatible with the F-4, F-15, F-16, and **F-1 11** aircraft.

Hardened Target Munitions.–The Air Force Armament Lab is planning a development program, beginning in 1987, to examine several advanced concepts for hard target penetration, including a "smart" fuze that could be adjusted to detonate the bomb only after several layers of concrete and voids had been penetrated (which would allow the bomb, for example, to penetrate a selectable number of floors through a building), and rocket-boosted penetration, discussed below

Durandal.–France has developed a 500-Ib bomb which is deployed on a parachute; when the bomb has decelerated and is aiming toward the ground at an angle, the parachute is jettisoned and a rocket motor ignites, driving the bomb into the target. The fuze sets the bomb off after a delay to allow it to reach an appropriate depth. The Air Force has purchased the Durandal as a stopgap while the BKEP (see below) is developed; but it is generally considered a cumbersome weapon for its intended purpose because it is a large unitary weapon—each one making only one hole—requiring many sorties before a runway is covered with enough holes to make it unusable over its entire length. It is also not suitable for use as a guided weapon in its current form.

BKEP, JP-233, STABO, ASW.–All four of these submunitions are much smaller weapons than the Durandal[11] and are designed to be deployed by a dispenser (BKEP in a tactical munitions dispenser or a dispenser version of the AGM-130;[12] STABO and ASW in the MW-1; and JP-233 in a similar dispenser also built for the Tornado aircraft). All use some form of boosted penetration; BKEP, which is slated by the Air Force for full-scale development in fiscal year 1986, and JP-233, a British weapon that the Air Force was at one time participating in the development of, are quite similar in operation to the Durandal. The STABO, and the ASW (designed to penetrate aircraft shelters), use a shaped charge to create an entry hole in the target on contact and then ignite a small charge to drive in the projectile; a time delay sets off the main charge.

None of these submunitions can themselves be guided; rather, they seek to make up for a lack of terminal accuracy in numbers, blanketing the target area.

Soft Area Targets

Soft targets–surface-to-air or surface-to-surface missile launchers with their associated communications and radar trucks, supplies and trucks in a depot, field headquarters—are generally movable (rather than fixed, as bridges; or mobile, as tanks) and spread out over some area. The principal weapons against these targets are cluster bombs that contain fragmenting bomblets. Smart weapons are also being considered for the special case of surface-to-surface missile launchers which can relocate after firing; it is the firing that gives away its position, but by the time that a munition can be delivered against it, the launcher will be on the way to a new and safer position and may be a half a kilometer or more away.

APAM.–The conventionally armed Lance missiles are—and at least the first batch of ATACMS (referred to as ATACMS Block 1) will be–armed with antipersonnel/anti materiel (APAM) clusterbomb submunitions designated M74; these are spherical, baseball-sized bombs with a tungsten fragmenting case. The ground pattern can be controlled by the height at which the warhead is fuzed to air-burst. The APAM is ineffective against armor.

AMIS.– Diesel fuel is an attractive target, both in supply dumps and in light vehicles; but it is relatively hard to ignite. The AMIS, or antimateriel incendiary submunition, breaks into fragments designed principally to pierce truck fuel tanks, producing a mist of diesel fuel; an incendiary then ignites the vapor. It is designed to kill a diesel-fueled vehicle at a range of **40** feet. The AMIS is designed to be carried in a standard aircraft tactical munitions dispenser, 30 per dispenser load. Advanced development has been completed, and the Air Force has no plans at present to continue with the program.

Focused-Fragment SADARM.—TO be effective against an imprecisely located surface-to-surface missile launcher, a munition will need to have a very large kill radius. A program to develop a smart submunition for this task, to be used in an ATACMS missile (designated ATACMS Block III), is beginning in fiscal year 1986. Both SADARM and TGSM submunitions are candidates.

To be effective as an area weapon against soft targets, the SADARM's explosively formed penetrator rod would be replaced with a "focused fragment" warhead that produces a large number of larger-diameter, though shorter, fragments. (Against lightly armored or unarmored targets the single long explosively formed penetrator is relatively ineffective: it owes its lethal effect to the

[11] The BKEP for example, is 4 inches in diameter and 43 inches long and weighs only 45 lbs, of which a mere 6.5 lbs is high explosive—as against the 500 lb Durandal.

[12] The actual deployment for airfield attack would contain a mix of BKEPS (to damage the runways) and mines (to hinder repair operations) in each dispenser load.

spalling that occurs when it strikes heavy armor. When it strikes a truck, for example, it simply forms a small hole and passes right through without producing any collateral damage.)

The large search "footprint" needed to cover the wide target area would be achieved by improving the SADARM sensor and by dispensing many SADARMs—the SADARM is smaller and less expensive than the TGSM, which makes this a reasonable idea.

Large-Footprint TGSM.–In order to search out a greater area on the ground, a TGSM for ATACMS Block III will require an improved seeker able to detect and begin homing in on the target from a greater distance. Two technology projects are now under way, looking at a dual-mode seeker, which combines IR and millimeter wave in a single seeker, and an imaging infrared seeker, which produces a picture-quality infrared image of the scene containing far greater detail than the very "patchy" digital picture of the conventional IR seekers. The advanced technology seekers could also be incorporated into the ATACMS Block II at a later stage to improve their antiarmor capability.

Costs are uncertain at this stage; estimates range from **$20,000** to **$50,000** per TGSM.

Glossary

AAFCE –Allied Air Forces Central Europe: the NATO air force command for the Central Region

ACE –Allied Command Europe: ACE includes the Central Region and both the northern and southern flanks, and is commanded by SACEUR

AG —army group: a ground force command echelon in NATO; Army Groups in the Central Region are NORTHAG and CENTAG

AFCENT –Allied Forces Central Region

AGM —air-to-ground missile

AGM-130 —a short-range rocket-powered air-to-ground missile derived from the GBU-15

ALB –AirLand Battle: U.S. Army doctrine (endorsed by the U.S. Air Force as appropriate) for the conduct of army operations

AMIS —antimateriel incendiary submunition

AMRAAM —advanced medium-range air-to-air missile

APAM —antipersonnel/antimateriel munition: the warhead carried by the conventional version of the Lance missile and by block I of the ATACMS missile

Aquila –U.S. Army-developed remotely piloted vehicle

ASAC —All-Source Analysis Center

ASARS II –Advanced Synthetic Aperture Radar System II: a U.S. Air Force high resolution ground surveillance imagery radar system, which can detect stationary objects

ATACMS –Army Tactical Missile System: a ballistic missile, also called Army TACMS, or TACMS

ATAF –Allied Tactical Air Force: an air force command echelon in NATO; ATAFs in the Central Region are 4ATAF and 2ATAF

ATOC —Allied Tactical Operations Center: a NATO C^2 facility for offensive and supporting air operations in the Central Region, subordinate to the ATAF; there are four ATOCs in the Central Region

BE –Belgium (NATO designator)

C^2 —command and control

C^3 —command, control, and communications

C^3I —command, control, communications, and intelligence

CEM —Combined Effects Munition: Air Force cluster bomb

CENTAG –(NATO) Central Army Group: made up of four corps in southern Germany

CGSC –Command and General Staff College of the U.S. Army

CHOP —change of operational control: from national commanders to NATO commanders

CINCENT –(NATO) Commander-in-Chief, Central Region: the commander of AFCENT

COMAAFCE –(NATO) Commander, Allied Air Forces Central Europe: the commander of AAFCE

DARPA –Defense Advanced Research Projects Agency

DPICM –dual-purpose improved conventional munition

ECM —electronic countermeasures

ECCM —electronic counter-countermeasures

EO, or E-O —electro-optical: TV-like, employing vacuum tubes or semiconductor devices to convert optical (visible, ultraviolet, or infrared) radiation into electrical currents

ERAM —extended-range antiarmor mine

FASCAM –family of scatterable mines

FLIR –forward-looking infrared: an airborne system for locating targets and controlling weapons at night

FLOT –forward line of own troops: the approximate point at which opposing ground forces are in contact; sometimes used in the sense of a “battle line”

FRG –Federal Republic of Germany

front —a Soviet command echelon above “army”

FSCL –fire support coordination line: a line established at approximately the range of fire of NATO artillery, or about 25 to 35 km into enemy area across the FLOT

GATOR —air-delivered antitank and antipersonnel mines

GBU-15 —a Glide Bomb Unit, which is “thrown” by an attacking aircraft and guided toward the target from the aircraft, but which has no propulsion of its own

GE –West Germany (NATO designator)

GSM –Ground Station Module: a mobile ground station being developed by Motorola for the U.S. Army for use with the Joint STARS airborne radar system

1-2000 —improved 2,000-lb bomb, designed to penetrate hard targets

IFF —identification of friend or foe: the process of attempting to determine whether vehicle or unit (etc.) belongs to friendly forces, enemy forces, or neutral parties

IGB —inner-German border: the boundary between West and East Germany. Sometimes called the inter-German border

IR —infrared

IIR —imaging infrared

JSTARS —see Joint STARS

JTACMS –Joint Tactical Missile System; joint Army-Air Force development program for medium-range conventional cruise missile

Joint STARS –Joint Surveillance Target Attack Radar System: a developmental airborne radar system carried on C-18 aircraft intended to locate fixed or moving targets on the ground and to control attacks against such targets using tactical aircraft or guided munitions

LANTIRN –Low Altitude Navigation and Targeting Infrared System for Night: a system for low altitude all-weather navigation and targeting for tactical aircraft

LOC –lines of communications

LOCPOD –Low Cost Powered Off-Boresight Dispenser: NATO development project for air-launched submunition dispenser

LRSOM –Long Range Standoff Missile: a tri-national (U. S., U. K., FRG) feasibility study for a long-range cruise missile

Maverick –guided short-range air-to-ground anti-armor missile used by the U.S. Air Force

Mk-82 –general-purpose 500-lb bomb

Mk-84 –general-purpose 2,000-lb bomb

MLRS —multiple launch rocket system

MLRS/TGW —terminally guided warhead for the MLRS

M M W —millimeter wave

MTI —moving target indicator: a type of radar useful for surveillance of moving objects such as aircraft or ground vehicles

NL –Netherlands (NATO designator)

NORTHAG –NATO Northern Army Group: four corps in northern half of Germany

Paveway –laser-guided bomb used by the U.S. Air Force

PAVE TACK–a forward-looking infrared pod carried by aircraft to locate targets at night and control laser-guided bombs

PLSS –Precision Location Strike System: an airborne surveillance and control system carried on TR-1 aircraft intended to detect, identify, and accurately locate advanced (pulsed, frequency-hopping) enemy radar transmitters and some types of jammers in near real time and to guide weapons or aircraft to such targets with sufficient accuracy to destroy them; the continuation of the program is currently in question

PLSS GS —PLSS Ground Station

RPV —remotely piloted vehicle: usually referring to a small aircraft that communicates with and is guided by a control station

SAC –Strategic Air Command of the U.S, Air Force

SACEUR –(NATO) Supreme Allied Commander Europe: the commander of NATO forces throughout the European theater, which is also known as ACE

SADARM —Search and Destroy Armor; smart anti-armor submunition for surface-to-surface weapons

SAM —surface-to-air missile

SAR —synthetic aperture radar: often used for obtaining high-resolution radar images of objects on the ground

SFW –Sensor-Fuzed Weapon; see Skeet

SHAPE —Supreme Headquarters Allied Power: Europe: the headquarters for SACEUR

Skeet —smart puck-shaped antiarmor submunition which can sense a target and send an explosively formed penetrating fragment towards the target at high velocity

SRSOM –Short-Range Standoff Missile: a NATO project currently in the feasibility study stage

SSM —surface-to-surface missile

STARS —see Joint STARS

TACAIR —tactical aircraft

TACMS –Tactical Missile System; see ATACM

TERCOM —terrain comparison

TGSM —terminally guided submunition: smart antiarmor submunition under consideration for ATACMS missile

TGW —Terminally Guided Warhead, under development for MLRS rockets

TMD —tactical munition dispenser

TRS —Tactical Reconnaissance System: an airborne reconnaissance system which ineludes the TR-1 aircraft, TR1 GS or TREDS ground stations, and other associated equipment

U.S. GOVERNMENT PRINTING OFFICE : 1986 0 - 60-901