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EXTENDED-RANGE SMART CONVENTIONAL WEAPON SYSTEMS

A Paper by the Standoff Weapons Panel, Offense-Defense Working Group, submitted to the Commission on Integrated Long-Term Strategy

October 1988

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The Report of the Commission on Integrated Long-Term Strategy, Discriminate Deterrence, was published in January 1988 and is available for sale by the Superintendent of Documents, US Government Printing Office, Washington, DC 20402 for $6.50.

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COMMISSION ON INTEGRATED LONG-TERM STRATEGY

MEMORANDUM FOR THE COMMISSION ON INTEGRATED LONG-TERM STRATEGY

The Panel on Standoff Weapons of the Offense-Defense Working Group is pleased to present to the Commission on Integrated Long-Term Strategy our paper on "Extended-Range Smart Conventional Weapon Systems."

This paper is in consonance with the Commission's report, Discriminate Deterrence, which made use of our preliminary findings. Our findings are also represented in The Future of Containment: America's Options for Defending its Interests on the Soviet Periphery, the report of the Offense-Defense Working Group. This paper provides more comprehensive and detailed information in support of both the Commission's and the Working Group's report. However, the paper is the responsibility of its authors, and neither the Commission nor the Working Group necessarily subscribe to all its details.

The paper reflects comments and criticisms on earlier drafts by a number of people, including other members of the Offense-Defense Working Group. We also thank William Konick and Rick Menz, both from the Office of the Secretary of Defense, for providing the data on munitions funding.

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MAIN POINTS

The Report of The Commission on Integrated Long-Term Strategy stresses the need for a comprehensive strategy to help guide the decisions we face about force development, weapons procurement, arms control, and other national security matters. Some of the most critical questions involve applications and consequences of new technology; the history of technology demonstrates that invention is often the mother of necessity. Smart conventional weapon systems are one of several classes of military technologies with the potential to profoundly influence future warfare. A subset--extended-range weapon systems to attack ground targets--may be a particularly important element in improved U.S. and North Atlantic Treaty Organization (NATO) conventional force postures.

This paper summarizes the promise of extended-range, ground-attack weapon systems, identifies obstacles to the realization of this promise, and offers several recommendations. Although these weapon systems can be consequential in low intensity and Third World conflicts, the emphasis here is on their contributions to stop, and thus help deter, attacks by the Soviet Union against the U.S. and our allies. These contributions eventually may be considerable; however, smart weapons, extended-range or otherwise, are not a high-technology panacea to our conventional force deficiencies. Modern combined arms combat requires a subtle balance among its various elements. Furthermore, non-materiel factors--tactics, training, leadership, morale--are critically important.

Some rough, if somewhat arbitrary, definitions are in order. A "weapon system" is more than a missile vehicle and warhead. The system may also include elements for surveillance, target acquisition, discrimination, and battle management/command, control, and communication (BM/C^3). "Ground attack" defines the location of the intended targets; the missiles themselves could be ground-, air-, or sea-launched. "Extended range" is greater than several tens of kilometers, i.e., beyond artillery range. The term "smart" applies to weapons that receive information during flight--from on-board systems and/or external sources--to help acquire and select targets, recognize and defeat countermeasures, and position and orient payloads. The category is not limited to fully autonomous weapons nor intended to imply weapon brilliance or genius. Indeed, not dumb (or competent, in the vernacular of some in the Pentagon) may be a more appropriate descriptor than smart.

This paper develops four principal themes. First, extended-range weapon systems will be increasingly important in military operations. Second, it is plausible, but by no means certain, that over a long period of time their effect will favor the U.S. and our allies and thus may lead to a more stable conventional deterrent. Third, the most likely payoffs from extended-range smart systems during the next 10-20 years will not be against mobile and moving targets deep in the enemy's rear, but rather against other targets including shallow mobile, fixed, emitting, and rail. Last, unless we change the way we do business, we are unlikely to achieve significant benefits.

I. THE CONTEXT

A. THE COMPLEMENTARY ROLES OF CONVENTIONAL AND NUCLEAR WEAPONS IN DETERRENCE

Our nuclear forces bear the brunt of the responsibilities to deter nuclear attacks and coercion against the U.S. or our allies. The nuclear forces also share responsibilities, along with our conventional forces and those of our allies, to deter non-nuclear aggression. Opportunities to substitute conventional for nuclear forces must be placed in an appropriate context. However, the context is frequently unstated or ignored, and, thus, claims about substituting conventional for nuclear weapons are often misleading or misinterpreted.

There are at least three perspectives from which to view the role of extended-range conventional weapons and their relation to nuclear weapons. These will, with considerable semantic license, be characterized as the targeteer's, the strategic, and the campaign perspectives.

Least useful, but all too prevalent, is the perspective of the targeteer. This perspective focuses on the weapon-target interactions and is characterized by a target-by-target comparison of nuclear and conventional weapon effectiveness. The objective is to identify targets, currently covered by nuclear weapons, that may be adequately attacked by improved conventional weapons.

However, merely identifying some targets that can be attacked by improved conventional weapons tells little about the respective roles of nuclear and conventional forces. Target damage needs to be placed in the context of specific situations. Each side's objectives and strategies must be considered. Context-free targeting and target damage assessment has too often served as a convenient but hardly adequate surrogate for establishing coherent nuclear strategies. We will not attain the potential value of improved conventional weapon systems if the targeteer's perspective is allowed to dominate in this realm as well.

Nuclear weapons cannot be traded off for conventional weapons on the basis of a target-by-target analysis. The trade-offs must be done at a much higher level: between our nuclear and conventional forces. Furthermore, the trade-offs must account for the several missions (shared and independent) of these forces. For example, the role of our theater nuclear forces to deter nuclear aggression will become more important if we are successful in improving our conventional force posture.

The strategic perspective looks beyond targets and considers the potential of extended-range conventional weapon systems to provide new escalation options. The intent is to bridge perceived gaps in our deterrent posture. The strategic perspective recognizes that deterrence depends upon the Soviet's perception of the likelihood as well as the severity of the threatened response. Thus, a conventional response could be viewed as more credible than a nuclear one in this age of nuclear parity. The challenge is to identify conventional attack options that both provide consequences sufficiently inimical to the Soviets to deter certain actions and at the same time will be less escalatory than nuclear strikes. Attacks upon their power generation and distribution and space launch capabilities are among the options that have been examined.

The campaign perspective seeks to improve our capabilities to resist Soviet non-nuclear aggression by non-nuclear means. Improved conventional weapons are but one of the many tools at our disposal to enhance our conventional force posture. Better training, transport, and logistics are among the others. The objective is to reduce our reliance on the (decreasingly credible) threat of nuclear escalation (particularly early escalation) to deter non-nuclear aggression. This was a worthy goal before the Intermediate-Range Nuclear Force (INF) Treaty. It is at least as important in the post-Treaty environment. The Soviets' willingness to initiate war will be reduced if they perceive little likelihood of quick success. Controlling their allies is one of the problems they would face in longer conflicts.

The strategic perspective reflects our capability to escalate and deliver consequences (pain or punishment) that a potential aggressor will perceive outweighs any gains of aggression. The campaign perspective--often characterized by the terms direct defense and deterrence by denial--addresses a capability to thwart the military objectives of the aggressor directly. The two perspectives are complementary. Boundaries between them cannot be drawn unambiguously. Distinctions between direct and indirect effects and thus between denial and pain or punishment are subjective. Indeed the term strategic, as in strategic bombing, also connotes the rendering of an enemy incapable of making war. The strength of the strategy of flexible response depends on its integrity. Subjecting elements of the strategy to isolated analysis exaggerates its weaknesses.

The perspective of this paper is that of the campaign: how to strengthen deterrence by improving our capabilities to defend against Soviet non-nuclear attacks. A critically important, if not the most likely, arena for such attacks is NATO's central region.

B. NEW MILITARY CAPABILITIES AND CONVENTIONAL DETERRENCE: NATO'S CENTRAL REGION AS AN ILLUSTRATIVE CASE

A simplified model of the central region balance gives the Warsaw Pact (WP) the advantages of the first blow, shorter logistic lines for its senior partner (compared to those of

NATO's senior partner), an adversary with little strategic depth, and, in general, greater quantities of men and materiel. NATO's advantages include greater knowledge of the terrain (its forces train and practice on terrain they would defend in war) and generally superior technology and training (although not across the board).

NATO also has the, presumably more modest, objective of holding rather than gaining territory. However, this must be balanced against the aggressor's advantage of striking first. The net effect depends on the tactics and technology of the time. For example, the technology of the late 19th century--rifling, breech loading, rapid fire, barbed wire--helped contribute to the dominance of the defense during much of World War I.

The tank and the airplane were major ingredients (the lowly truck was also a significant contributor) of the shift to a quite different type of warfare. Initiative and the first blow now gave the attacker considerable advantages: achieving surprise, if only tactical; keeping the defender off balance; and gaining local superiority to accomplish the breakthroughs and flanking maneuvers that can lead to decisive victories. If this model of large-scale conventional war persists, then there are very real limits to the extent that NATO can increase its reliance on conventional defense to deter non-nuclear aggression.

Thus, a fundamental issue is what, in the aggregate, will be the effect of new technologies on the conventional offense/defense relationships. Weapons and other accouterments of war are by themselves neither offensive nor defensive. However, a plausible case can be made that the overall effect of the new technologies will tend to favor the defense. If this is so, then NATO will have affordable options, consistent with its strategy, to increase reliance on its conventional forces to deter non-nuclear aggression. In any event, the threat of nuclear escalation likely will continue to contribute materially to deterring war.

The technologies contributing to intelligence, surveillance, smart weapons, and barriers may make it more difficult for the attacker to gain the local superiority needed for breakthroughs, as well as diminish the value of armored fighting vehicles so critical to achieving and exploiting breakthroughs. Extended-range, smart weapon systems, for the reasons discussed in the following chapter, may be a particularly significant card in strengthening a defender's hand.

II. THE PROMISE OF EXTENDED-RANGE, SMART WEAPON SYSTEMS

Extended range provides flexibility: in targeting, in employment, and in deployment. "Smart" holds the promise of greatly improved payloads. The combination of the two attributes, flexibility and payload effectiveness, offers the potential for profound military effect. This chapter summarizes the virtues of this flexibility, the challenges of achieving greater payload effectiveness, and the means of delivering these payloads.

A. FLEXIBILITY

There is a tendency to equate the value of extending range to striking deeper. Attacking targets in the enemy's rear is indeed an important attribute of extended-range weapons; however, it is by no means the only one. The value of standing off from targets--to enhance survival--is also generally acknowledged. Less widely appreciated (although well known to all artillerymen) are the values of reaching laterally along the front (or FLOT - Forward Line of Own Troops) and of delivering firepower rapidly compared to other means. This flexibility--to strike deep, reach laterally, stand off, and respond rapidly--can make a potent contribution to a more effective conventional force posture.

1. Reach Beyond the FLOT

The capability offered by extended-range weapon systems to strike deeper into the enemy's rear has received the most attention. The Follow-On Force Attack (FOFA) concept has been the focus of much of this effort. The feature is also embodied in the recent attention given to non-nuclear strategic systems, the subject of a 1987 Defense Science Board study. The objective of FOFA is to delay, disrupt, and decrease enemy forces before they engage friendly forces and thus prevent enemy saturation of the defenders at the FLOT. The concept is argued most persuasively, not as a strategy in itself, but as a necessary element in a balanced conventional force posture: to prevent the attacker from maintaining the momentum of his assault.

Long-range, conventionally armed weapons could be particularly valuable against short mobilization attacks. The delivery of these weapons--from tactical aircraft based in the theater and long-range bombers positioned externally, from submarines or surface ships, and from ground-based Transporter Erector Launchers (TELs)--could produce crucial delays in Warsaw Pact troop movements by attacking bridges; command, control, communication and intelligence (C^3I) nodes; transloading points; maintenance and logistic facilities; and rail traffic. These delays hamper the formation of local Warsaw Pact force concentrations and, therefore, could significantly reduce the Pact's ability to move against the hasty defenses that NATO would be able to mount under the circumstances of short mobilization. Similarly, by attacking airfields, surface-to-air missile (SAM) sites, radars, and electronic warfare facilities, extended-range weapons could be a valuable complement to penetrating aircraft for offensive counterair and defense suppression missions.

The use of smart, long-range missiles would be especially critical early in the conflict. In the early days of a war, NATO will be fighting for air superiority. Therefore, there will be a great demand for aircraft sorties devoted to the air superiority contest and fewer sorties available for close air support, battlefield air interdiction, and deep strike. Moreover, the initial waves of a Warsaw Pact attack could temporarily suppress NATO air bases and reduce NATO sorties. Once air superiority and defense suppression are achieved, NATO's tactical air force can shift its emphasis to attacking ground targets and be able to rely more on shorter range weapons.

The introduction of low-observable, fighter-bomber aircraft may provide a capability to perform deep penetration missions through the formidable defenses that would exist early in the conflict. However, these aircraft will probably constitute only a small percentage of the overall NATO aircraft inventory for the next 20 years and air base operability will likely continue to be a concern. Most current U.S. military aircraft are projected to have active service lives well in excess of 30 years. Utilizing bombers (and ships) already in the inventory for delivery of extended-range weapons relieves some of the force structure problem and keeps available fighters in more optimum (e.g., air superiority) roles.

2. Reach Laterally Across the FLOT

The capability to reach laterally is the other dimension of the targeting flexibility offered by extended-range weapon systems. Although it receives less attention than the deep strike role, it may turn out to be as important.

The weakness of a defensive posture is that it leaves the initiative to the attacker. History amply demonstrates the resourcefulness of attackers for achieving decisive victories, sometimes over equal or even larger forces, by gaining local superiority at the right times and places.

Extended-range weapons may help redress this classic vulnerability of the defense. They can mass fire where enemy forces mass, from dispersed--and thus more survivable--positions. This greatly reduces the absentee ratio of the defender's assets: nearly all the weapon systems can get into the fray and contribute to stopping enemy penetrations, either classical breakthrough challenges or Operational Maneuver Group (OMG) efforts to penetrate deep behind NATO's lines. Thus, in Deputy Under Secretary Donald Fredericksen's apt boxing analogy, extended-range, smart weapons--supported by robust eyes, ears, and communication links--may help the defender develop into a superb counterpuncher and neutralize the aggressor's present advantages.

On the other hand, if the new capabilities improve effectiveness against only fixed targets, then the outcome will be quite different. Thus, an equivalent increased ability by both NATO and the WP to attack fixed targets would favor the WP because of NATO's current greater dependence on such assets (e.g., airfields and ports).

NATO's corps each cover approximately 100 km of front, and thus ground-launched missiles with ranges of a few hundred kilometers can provide cross-corps support against enemy force concentrations. For example, consider a weapon with a range of 20 km, set one-third of its range behind the FLOT. From this position, it can cover almost 40 km along the FLOT, as well as over 360 km^2 beyond the FLOT (assuming a linear FLOT). Increasing its range to 200 km (and again positioning it one-third of its range behind the FLOT) increases its coverage along the FLOT tenfold (to over 370 km, i.e. three to four corps fronts) and beyond the FLOT a hundredfold (to over 36,000 km^2). Moving the weapon closer to the FLOT, e.g., at the same setback as the shorter range weapon, will almost double again the coverage beyond the FLOT (to over 60,000 km^2).

An important implication of increased range is that fewer weapons are required to provide coverage of the entire front. To protect against attacks that may come anywhere along the FLOT, the shorter range weapons must be in position everywhere along the FLOT. In most cases there would not be enough time to redeploy them. From a purely geometric standpoint, and ignoring any differences in effectiveness, the number of weapons required is inversely proportional to their range. Thus, a few batteries of the 200 km range weapons can cover the entire 800 km front, a 10th of the number of 20 km range weapons needed. In reality the range leverage will be less--although still significant--than this simple geometric derivation, due both to command and communications problems and the need to cover more than one breakthrough challenge simultaneously.

Thus, the cross-corps support--concentrated firepower from widely dispersed positions--provided by extended-range weapons can be a vital complement to shorter range systems (infantry-fired, line-of-sight antitank weapons, artillery, etc.). However, necessary conditions to realize this complementarity include effective command, timely and survivable communications, and a weak dependence of system cost on weapon range. The last is likely to be the case for smart weapons, where much of the cost is in the guidance and/or payload. Furthermore, realization of maximum benefits from the flexibility of extended range may require changes to NATO's tactics or force structure. One such change could be assigning some of these weapons to command levels above corps: Army Group and Theater. (Some argue that this change is unnecessary; affordable BM/C^3 will allow corps to answer calls for fire.)

The capability for flexible target coverage--including lateral reach--has long been argued as a major advantage of tactical aircraft. Just as with the ability to strike deeper targets, the cross-corps role of extended-range weapon systems, launched from ground-based TELs and long-range aircraft, could be especially important early in the conflict when our tactical air forces are fighting for air supremacy.

The flexibility offered by extended-range weapons was recognized in the 1987 study by the Congressional Office of Technology Assessment on "Implementing Follow-On Forces Attack". The study observed that "If the follow-on forces are very important to Soviet strategy (and if they can be found and attacked effectively), FOFA could be enormously effective. However, if the follow-on forces play a less important role, FOFA would be less valuable **(although the weapons and other systems might not necessarily be any less useful). A FOFA capability could be used to compensate for Pact's advantage in lateral movement by redirecting the firepower of long-range weapons and interdiction aircraft along the front."** (emphasis added).

3. Standoff

The employment flexibility of extended-range weapons enhances their survival. For air-delivered weapons, a standoff capability reduces the risk to pilot and aircraft. Several kilometers of standoff allow the pilot to avoid flying over the target and greatly ease the problems of weapon delivery. Increasing the standoff to several tens of kilometers permits the pilot to avoid the terminal defenses surrounding high-value targets. Increasing the standoff to hundreds of kilometers or more could allow the pilot and aircraft to avoid almost all defenses (both area SAMs and interceptor aircraft).

The employment flexibility of extended range can also enhance survival of ground-launched weapons. The weapons can be dispersed and deployed over a greater area, laterally and deeper, while still providing widespread and overlapping target coverage. Such deployment would greatly complicate the attacker's objective of gaining local superiority at one or more places along the FLOT, even if the attacker has similar weapons. Furthermore, extended-range weapons, set well back from the FLOT, may not have to move as frequently as shorter range weapons positioned closer to the FLOT. Consequently, they will be in a position to fire more often. While the flexibility to deploy deeper in our own territory reduces vulnerability, survivability does not necessarily increase monotonically with setback from the FLOT. Other factors--uniqueness of signature, traffic density, ability to fire and relocate quickly--also influence survival.

4. Rapid Response

The capability to deliver firepower rapidly by extended-range weapon systems launched from aircraft based in the continental United States (CONUS) or from ships could become a vital element in our capability to respond, not only in NATO's central front, but also in contingencies worldwide. This attribute, closely related to the other three, reflects the temporal rather than the spatial dimensions of the flexibility offered by extended-range weapons.

In plausible future conflict situations, particularly on the periphery of the Soviet Union, the U.S. would likely face large significant asymmetries in ground and air forces at the onset of conflict. In these circumstances, rapid application of military force may be called for, often without the benefit of previously achieved air superiority. Extended-range weapons offer a means to mitigate the effects of the asymmetries. Typically, the leading edge (i.e., forces available during the first 1 to 2 weeks) of our military response would be aimed at slowing or delaying enemy movement until reinforcing ground, naval, and/or tactical air support can be brought into play.

For example, accurate standoff weapons might disrupt a Soviet thrust to the Persian Gulf through Iran by destroying key bridges and attacking troops in road march to delay the movement of Soviet troops through the Malyy Kavkaz and Caucasus mountains and by attacking forward air bases and cratering runways used to support Soviet aircraft. Thus, these extended-range weapons, launched from ships and from B-52s operating initially out of CONUS bases, and perhaps subsequently out of bases closer to the region, could buy time for the arrival of ground, naval, and tactical air forces. Extended-range weapons could also play a vital role in helping defend against (and thus deter) attacks by the Soviets and their allies elsewhere, including Korea and NATO's flanks in northern Norway and eastern Turkey.

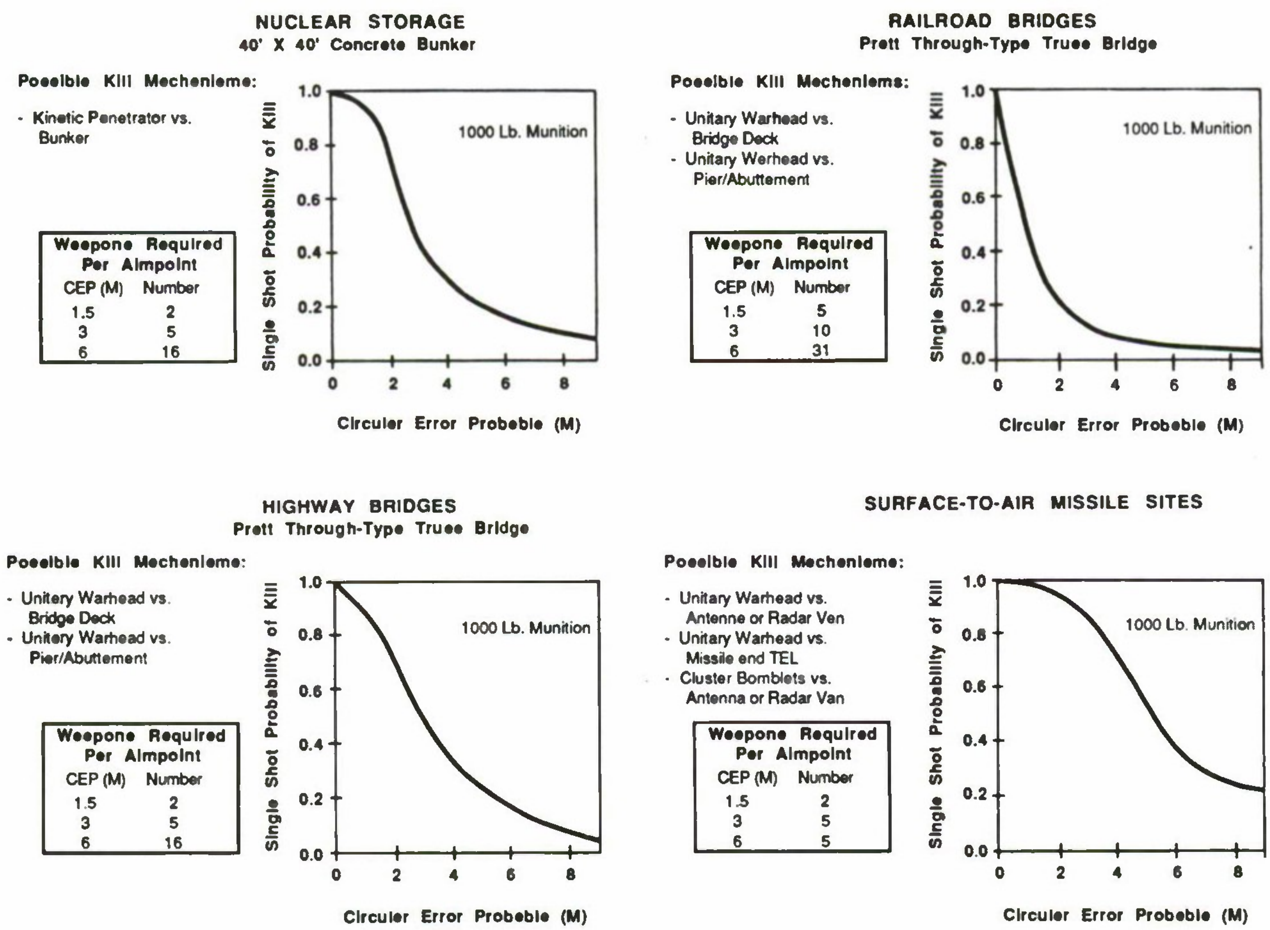
B. PAYLOAD EFFECTIVENESS

Extended-range weapon systems offer an impressive array of potential benefits: targeting flexibility (to strike deeper and to reach laterally), employment flexibility (to stand off from defenses and the FLOT), and deployment flexibility (to deliver firepower rapidly in response to contingencies worldwide). However, the realization of these benefits requires effective payloads against a variety of fixed, moving, and mobile targets. The promise of smart weapon systems is that they can do a better job of finding and distinguishing targets from non-targets, defeating countermeasures, getting closer to or actually hitting the targets, and transferring their destructive energy to the targets.

The technology exists to deliver payloads at great precision over long distances. Range-independent accuracies of approximately 15 meters can be achieved in all weather conditions, 24 hours a day, through a combination of relatively low-cost inertial navigation systems (INS) and the use of the space-based Global Positioning System (GPS). These accuracies will be sufficient to attack many targets effectively (e.g., air defense sites, some C^3 facilities), given the appropriate munition. Other targets (e.g., railway bridges) will require still greater accuracies. Higher precision alone will not be sufficient to achieve these greater accuracies even against fixed targets. It will also be necessary to address target location errors, which combine statistically with navigation errors to determine miss distances and the probability of damaging the target. Target location errors alone suggest that relative (terminal homing) navigation, rather than absolute (data base correlation) navigation, is necessary for extremely high accuracies. GPS will not be adequate for such accuracies. Accuracies of 1 to 3 meters may be achievable by using terminal homing and optimal trajectories (along with mid-course guidance to get the missile into a "basket" where the terminal system can take over).

Technologies applicable for terminal homing include imaging infrared (I^2R), laser ranging/imaging, millimeter wave, and synthetic aperture radars. Each has strengths and weaknesses. For example, an imaging infrared system is passive and may be least costly, but its performance is sensitive to weather conditions. All may find application in future terminal homing sensor systems, and preferred systems may involve combinations of the technologies. The following figure shows the effect of improving missile accuracy for several target classes.

CONVENTIONAL MUNITIONS EFFECTIVENESS AGAINST SEVERAL TYPES OF TARGETS



Moving and movable targets, particularly those deep in enemy territory, present greater challenges for today's technology. The objective is for weapons, in an autonomous search-and-destroy mode, to recognize and lock on to targets while rejecting false alarms under conditions of high noise and clutter. Technology has not yet accomplished this. Although significant strides may be expected in this area over the next 5 to 10 years, the weapons with this deep-search-and-destroy capability will probably not be available in quantity for 15 to 20 years. In the meantime, the extended-range weapons will likely find higher payoff against fixed, emitting, and rail targets and also shallow mobile targets that are under close tactical surveillance by standoff sensor systems (e.g., JSTARS), unmanned aerial vehicles (UAV), and humans (e.g., long-range patrols).

The technology of homing submunitions eventually may produce an affordable indirect fire capability against tanks. However, even if the tank remains too tough a target, there are other, softer elements of the combined arms threat that present attractive targets. Extended-range weapons carrying distributed area munitions can contribute to stopping invasions by attacking exposed troops, artillery, and lightly and unarmored vehicles.

Weapons with man-in-the-loop guidance systems, (i.e., within line-of-sight or data link range) may be very useful against some mobile targets and can be especially important for the cross-corps role of extended-range weapons against relatively shallow targets--within 50-100 km of the FLOT. Man-in-the-loop guidance also provides some measure of highly desirable damage assessment. Fiber optic links may offer an affordable means to provide man-in-the-loop capabilities without the risks associated with maintaining line-of-sight to the target until the weapon arrives. It cannot be overemphasized that weapons alone will not provide the desired capability. Even relatively shallow targets cannot be effectively attacked without a robust surveillance system and tightly coupled command and control.

The proof of these weapons is not how they will operate in a pristine environment against isolated targets. There is little doubt that the technology exists to operate extremely well under such conditions. It is, however, irrelevant to the modern battlefield. The effects of the fog of war and potential enemy countermeasures must be addressed from the beginning of the design process. There will be continued vigorous competition between the technologies of signature reduction, deception, agility, and hardening and the technologies of target acquisition, discrimination, weapon precision, and lethality.

There has been insufficient testing and supporting experiments of smart weapon systems under realistic battlefield conditions. The resultant paucity of relevant data has given an unnecessarily theoretical cast to the debates regarding the merits of smart weapons. Debates about battlefield nuclear weapons of necessity have a theoretical flavor because of the difficulties in gathering relevant data. However, there is no reason why the debates on smart weapons should be equally academic, susceptible to undue influence from the better debater or fancier visual aids.

Indeed, while the final test can come only in actual combat, there is much to be learned about smart weapon concepts and systems through experiments, field tests, and demonstrations that simulate the fog of war and potential enemy countermeasures. However, for these tests to be be truly useful, they must go beyond the all-too-common approach of merely counting successes and failures. Quality signature and background data must be taken. Sufficient instrumentation must also be provided--to assess the intermediate processes internal to the systems--so that the actual causes of failure can be discovered.

The recent Chicken Little tests are a major step forward. Chicken Little evaluated smart submunitions--Skeet, Search and Destroy Armor (SADARM), Terminally Guided Submunition (TGSM)

--against foreign targets and countermeasures. The countermeasures included nets, foliage, corner reflectors, and infrared (IR) decoys. The tests provided tens of thousands of target opportunities against many different vehicle types and yielded an order of magnitude more data against Soviet-type targets than previously existed. Chicken Little II is in progress and there are plans to institutionalize this critical activity.

C. DELIVERY MEANS

Delivery can be accomplished by either cruise missiles or rockets. Cruise missiles have engines that use oxygen from the air; rockets carry their own oxidizer. Rockets, in turn, can be characterized as ballistic or powered. Ballistic missiles complete fuel burnout relatively early in flight; powered rockets rely on motors to shape the trajectory throughout flight.

For missiles with ranges of less than a few hundred kilometers, the lower cost of the rocket motor offsets the penalty of oxidizer weight. The cost break-even point seems to be a few hundred kilometers; at about 150 km range, the Harpoon is a cruise missile, while the Phoenix and the Army Tactical Missile System (ATACMS) missiles are rockets.

Cruise missiles appear to offer the lowest cost options for range requirements beyond a few hundred kilometers but less than intercontinental ranges (i.e., less than 8,000 km). The advent of small, relatively low-cost, high-performance gas turbine and propfan engines, high-energy density fuels, and low-cost, all-weather, day-night, accurate guidance has made this technical choice possible. At the longer ranges, the shorter flight times of ballistic missiles may make them competitive for some missions. However, many target types are not sensitive to the flight time difference between cruise and ballistic missiles. The flight duration is only a part of the time delay between target acquisition and weapon arrival. Furthermore, the reconnaissance, acquisition, and discrimination abilities of the weapon itself, rather than the time of flight, likely will be the key to successfully attacking mobile and movable targets at long ranges. Additionally, the warning time provided by high flying ballistic missiles may be longer than that provided by stealthy cruise missiles. This difference may be relevant for certain classes of targets that can move rapidly on tactical warning.

Ballistic missiles also currently enjoy the advantages that accrue from the absence of active defenses against them except in areas protected by the Moscow Anti-Ballistic Missile system. Although they may not have the benefits of a free ride in the future (the deployed Soviet SA-12 has some antitactical ballistic missile capability), their relatively high velocities will continue to pose formidable problems for the defense. Trajectory shaping, either powered or aerodynamic, can also enhance survival against defenses. A significant new factor is the technology of low observables. Its use in the design of cruise missiles will greatly increase their survivability.

Cruise missiles can be developed to deliver warheads (weighing hundreds of kilograms) to within a few meters or less of fixed points at ranges in excess of 1,000 km. The standoff land attack missile (SLAM), a modified air-launched Harpoon with a Maverick I^2R seeker and a Walleye data link, is being considered for procurement by the Navy. Autonomous cruise missiles with conventional warheads, such as Tomahawk, have a demonstrated 1,250 km range capability; however, their accuracy as presently configured is not quite as good as the shorter range SLAM.

There are several technical solutions, depending on the mission and cost goals, that can achieve accuracies on the order of several meters. A minimum capability Automatic Target Recognizer with a low-cost GPS/INS guidance system may be the most cost-effective approach. Correlation and classification algorithms of high fidelity need to be demonstrated and effectively integrated to imaging sensors. Research and development during the last decade has produced some useful designs that are ready for full-scale engineering development. Achieving still greater accuracies will probably require the addition of active sensors, such as carbon dioxide (CO_2) lasers or millimeter wave radars, and precision guidance and control elements. However, the addition of these systems could increase the weapon unit cost by more than $100,000. (Some argue the cost increases would be much less.) The accuracy of the weapon also will depend on its terminal approach to the target. Achieving extremely high accuracies may require a relatively low-speed, gentle glide-slope approach to the target that, in turn, may call for a low-observable design to minimize the weapon's vulnerability to enemy defenses in the target area.

Cruise missiles sized to deliver a 400 kg warhead to a distance of 500 km weigh approximately 1,000 kg. These weapons would be suitable for launch by tactical and strategic aircraft, by ships, and by ground-based TELs (for missiles with ranges less than 500 km). The additional cost to provide a 1,400 km range capability is largely manifest as an increase in fuel and fuel tank weight. That results in a 1,500 kg weapon that is more suitable for naval platforms and heavy bombers such as a B-52. Ground-launched missiles with ranges between 500 km and 5,500 km are prohibited by the INF Treaty.

III. THE AFFORDABILITY CHALLENGE

Affordability is a subjective notion. A judgment depends on one's estimates of the benefits and costs, including the opportunity costs, of using our resources for this purpose.

The cost of extended-range weapon systems is a function of the required quantity and quality of not only the weapons themselves, but also the associated target acquisition and BM/C^3 elements. The required quantity and quality in turn depend upon the specific missions and objectives of the system. For the purposes of this paper, it is sufficient to distinguish between order of magnitude differences.

A. WEAPON QUANTITIES NEEDED: AN OPEN QUESTION

Tens to hundreds of weapons could be important for special operations such as the 1986 raid on Libya. Hundreds to a few thousand might be sufficient to make a significant contribution to stopping attacks, even by Soviet forces, against NATO's northern flank, in Southwest Asia, or in Korea. However the quantity of extended-range weapons needed to make a substantial difference against Soviet Union/Warsaw Pact attacks in NATO's central region will likely number many thousands or even a few tens of thousands. Quantities will depend on the specifics of the scenario. As will be discussed in the next chapter, there remains a lack of comprehensive and credible analyses of inventory requirements. Targeting requirements are illustrated in Appendix A.

Studies claiming high payoffs from lower numbers of extended-range, smart weapons underestimate the effects of the fog and noise of war and enemy countermeasures. Analyses invariably assume that acquired targets are a subset of the real target set. Rarely are the consequences of the generation of false targets addressed. Weapons will miss their targets and will be delivered at false targets and non-targets. Targeteers will make mistakes; smart and even brilliant weapons will be fooled. However, although the weapons will not be as efficient as some advocates argue, the numbers may still be far less than the quantities of "dumb" munitions required to provide equivalent effects. Thus, the effects of the better munitions will show up not only in targeting and employment, but in logistics and transport as well.

Because tens of thousands of weapons may eventually be required, the unit cost becomes a critical factor. Unit costs of millions of dollars translate into total procurement costs of tens of billions of dollars (not even including the required surveillance and BM/C^3 systems). While such costs cannot be dismissed out of hand as unaffordable (the affordability evaluation would depend on estimates of the system effectiveness and, thus, on the perceived value of the acquisition), they would certainly place great strain on an already strained defense budget. After an unprecedented 6 consecutive years of rising defense budgets, the U.S. is entering the fourth year of declining budgets. It is the rare commentator who predicts that the pendulum will swing back sharply in the near future.

Other factors exacerbate the affordability problem. What appears to be an implicit, but critical, U.S. defense planning assumption is likely to continue: no war for at least 3 to 5 years. The effect of this assumption is to emphasize objectives other than acquiring weapon inventories sufficient to fight a war. Moreover, the dilemma of "better versus good enough" is a very real one for these systems. Tomorrow may indeed bring significant cost reductions and/or performance improvements. Should we wait until we can gain the benefits of these improvements before we make large investments?

B. REQUIREMENTS MANAGEMENT

One must be careful to avoid trivializing solutions to the cost problems. Studies of problems (real and imagined) and solutions (practical and quixotic) abound. The problems involve establishing priorities and requirements as much as managing costs. We need to improve the acquisition process to establish --and modify when appropriate--performance and schedule specifications to better represent the opportunity costs of resource expenditures. The solutions to these problems are beyond the scope of this paper. However, the solution requires more than encouraging innovation and speeding up the acquisition process. Thus, in addition to the special "fast track" advocated in the Commission report, we need a "right track" approach for complex system acquisition. A right track would closely couple system architecture development to extensive demonstration testing, perform comprehensive system trade-offs, and provide serious early attention to cost and affordability.

A significant portion of the acquisition costs of military systems is due to institutional inefficiencies and frictions. Micromanagement, production quantity changes, and program discontinuities account for much of the costs in excess of what programs could cost. The Congress is often responsible in these cases. However, other factors also contribute to this excess. These factors include overrequirements and overspecifications that too often stem from inadequate cost/performance trade-off studies. They also include costly accommodations to minor changes throughout development, insistence on meeting requirements that proved to be tougher than expected, and the resulting changes to the orderly flow of work.

Particularly insidious is the problem of tougher-than-expected requirements. A particular performance requirement may originally be selected on the basis of its position on an estimated cost performance curve, i.e., at or below the knee of the curve. In other words, an explicit and rational decision is made not to expend resources disproportionate to the benefits. A few years later, well into development, it is often discovered that the cost of meeting that particular performance requirement is much higher than expected. The original estimate of the cost-performance curve was wrong. (That this is so often the case is also part of the problem.) However, by then there is a whole new cast of players and it is forgotten why the performance specification was originally selected: because of its position below the knee of the cost-performance curve. Instead, the requirement has assumed the legitimacy of a commandment, and, too often, valuable resources are devoted to fix the problem--which in many cases would better be solved by relaxing the performance specification.

Changing these customs will not be easy. Czars cannot legislate solutions. A fix will require a change in the culture. The military will need to stop treating requirements as absolutes and instead think more in economic terms: wants competing for scarce resources. The defense industry will need to be inspired to identify costs more realistically and to pursue cost reduction opportunities more vigorously, not only at the start but also throughout the course of a program. Lastly, Congress will have to acknowledge that it is part of the problem and act accordingly. One positive step would be to avoid simultaneously criticizing the Pentagon for both gold plating (establishing and pursuing marginally important performance improvements) and failing to meet original specifications. These mixed signals do not contribute to progress towards a more rational and effective acquisition process.

C. COST AND MANUFACTURING CONSIDERATIONS

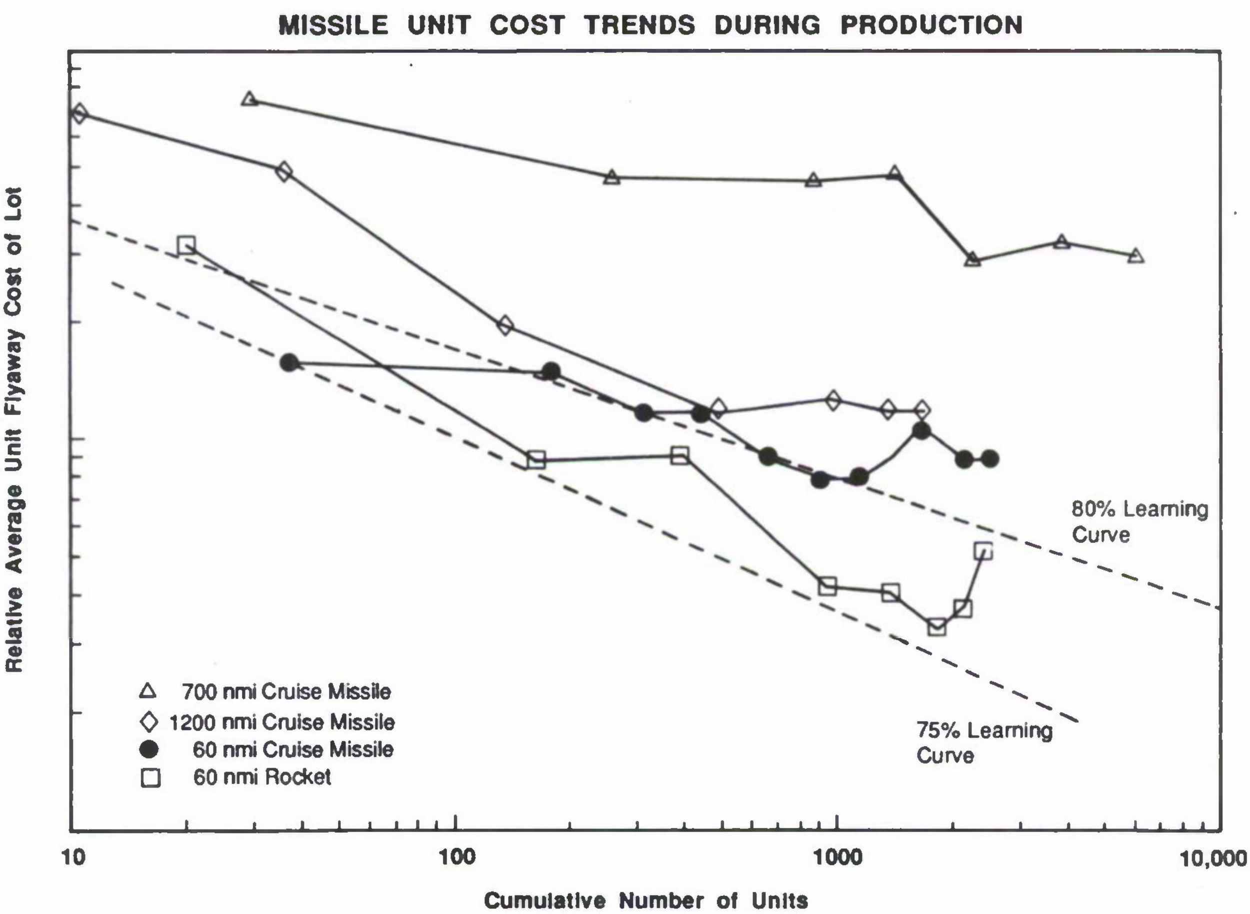
Three factors are major contributors to smart weapons costs: electronic weight, electronic complexity, and learning curve economies of scale or manufacturing techniques. Although electronic complexity continues to go up, specific electronic system weight is coming down due to the development of Very Large Scale Integration (VLSI) and Very High Speed Integrated Circuits (VHSIC). The net result of these offsetting trends frequently is an increase in cost. Thus, the savings due to decreasing electronic system weight and size are offset by the increasing complexity because the designer elects to raise the number of functions performed.

In addition, large production quantities may be needed to realize the cost benefits of VLSI and VHSIC because of the initial design and production costs associated with custom chip manufacture. Production quantities may be increased by adapting more of a modular, building-block approach to designing weapons instead of beginning anew with each new weapon design.

In the past, the emphasis generally was on increasing the performance of the individual weapon. Less attention was paid to questions of overall force effectiveness and affordability.

Production costs can frequently be reduced through mass production techniques and the process of learning through actual production experience. These economy-of-scale effects are often characterized by learning curves. If unit costs are plotted as a function of the total quantity produced, the amount of cost reduction achieved for every doubling of production quantity can be measured. Thus, a 90 percent learning curve implies that unit costs are reduced by 10 percent for every doubling of total production quantity.

There is some indication that learning curves of up to 75 percent may have been achieved in previous standoff weapon production programs (see the following figure). If these economies-of-scale can be achieved and if production quantities in excess of 5,000 units can be accomplished at steady production rates, then the unit costs for this class of weapon may be reduced by a factor of two. In addition, the use of flexible, automated manufacturing techniques may be able to flatten the learning curves out at average unit costs close to the minimum learning curve cost. This implies a commitment on the part of the manufacturer to invest in expensive manufacturing equipment. This is in the manufacturer's interest only if the expected production runs are large enough to make the initial equipment amortization a small part of the average unit cost. Thus, a long-term Government commitment is necessary not only to acquire enough of these weapons to be militarily important, but also to reduce the average unit cost so that these quantities are affordable. Unit missile costs of $500,000 or less should be possible through requirements management to avoid overspecification, and the application of a modular design approach that will support production quantities sufficiently large to achieve economies of scale.



One reason that standoff weapons have not achieved costs below about $1 million each is that their production runs are usually truncated at less than 5,000 units. Often the justification is that there is a new and better technological option. Thus, we rarely achieve the economies of scale and steady production runs that can significantly reduce the costs and provide enough weapons to be militarily significant. The advent of low-observable technology may have justified the decision to replace the Air-Launched Cruise Missile (ALCM) with the Advanced Cruise Missile (ACM), but such a significant technological change does not happen very often.

Reliability is another factor with important cost implications. Some standoff weapons, e.g., the ALCM and Tomahawk, are designed as "wooden" rounds on which very limited maintenance and repairs are performed in the field by operating forces. Equally important, very limited testing can be performed on wooden rounds in the field to ascertain the readiness of the system. Under this design concept, the Quality Assurance/Quality Control (QA/QC) procedures implemented at manufacturing sites in large measure determine the operational reliability of the weapons. Current QA/QC procedures and design characteristics of standoff weapons may require changes before adequate system reliability can be established and accurate costs can be computed. The desire for wooden rounds is a critical cost driver. Problems in this area have been especially troublesome for strategic weapons, with their very high reliability specifications. Considerably relaxed reliability requirements should be possible for tactical weapons, compared with strategic weapons. The manpower costs for supporting complex systems is high, and thus the wooden round philosophy should be expanded, but with realistic reliability specifications.

IV. OBSTACLES: BUREAUCRATIC AND OTHERWISE

With its emphasis on the virtues of range in addition to striking deep, the focus of this paper may be somewhat different from other treatments of extended-range weapons, but its basic message is not new. Many studies have hailed the promise of smart weapons; a particularly articulate example is the European Security Study: Strengthening Conventional Deterrence in Europe. Furthermore, the Defense Guidance and other Department of Defense (DoD) documents call for a significant role for smart weapons. However, progress has been slow. Formidable obstacles--as much bureaucratic as technical--impede realization of the promise of extended-range, smart weapon systems. Indeed, unless we change the way we have done business, the potential payoffs will remain just that: potential. The affordability challenge has already been covered. Eight other obstacles are examined in the following discussion. Several are closely related to each other; others are not unique to the smart weapon problem. More important, the list undoubtedly is not comprehensive (an extensive discussion of problems is provided in the 1985 report of the Defense Science Board (DSB) Task Force, which focused on the acquisition management process for ground-attack munitions).

A. EXAGGERATED CLAIMS AND UNREQUITED EXPECTATIONS

There appears to be considerable skepticism among the professional military and elsewhere regarding the benefits of smart weapons. Not all, or even most, of this skepticism can be attributed to institutional ludditism. There is ample evidence of overselling. Certainly, the development of these weapons has proved to be more challenging than many advocates expected. One of the authors received his first SADARM briefing from the Army in 1973; the claim was that it would shortly be in the inventory. Fifteen years later the same claim is made. Likewise, the Air Force's Sensor-Fuzed Weapon has been in development for over a decade.

The overoptimism regarding the pace of success of smart weapons reflects the history of artificial intelligence and related fields that support "smartness" in weapons: great expectations in the early days (the 1960s), followed by disillusion, and again rapidly rising expectations. The lack of early success was in part due to unavailability of the necessary hardware (it had not yet been invented). The more recent rise in expectations is in part fueled by dramatic enhancements in hardware and associated software.

Along with overly optimistic claims regarding the pace of progress, expected performance has been exaggerated. Near-unity kill probabilities are unlikely to be achieved. Claims of such high effectiveness raise false expectations and undermine the search for more modest, but still significant, capabilities. For example, near-unity kill probabilities of indirect fire against armor are not needed in order to introduce major changes on the battlefield, where the effectiveness of indirect fire against armor historically has been measured in small fractions of a percent.

B. TOO MUCH ATTENTION TO THE HARDEST PROBLEM

There appears to be disproportionate attention to the most technically challenging problems. Finding and attacking mobile missile launchers is the prime example. The challenges of finding and destroying small, agile targets (such as medium- and long-range missile launchers) deep in enemy territory can send many a technologist's heart aflutter. However, it is not apparent that these problems will yield to solutions over the next few decades. In the meantime, solutions to other less technically demanding problems would have a high payoff to improving our conventional capabilities. For some classes of mobile targets (e.g., armored formations moving to the battle staging area from their assembly areas), the very characteristics that make them dangerous--size, density, position, and velocity--also provide opportunities for us to detect them and discriminate them from other targets, false targets, or non-targets. Artillery could also be a high-payoff target set given its preponderance and importance to Soviet offensive operations. Likewise, trains on tracks and rear convoys on roads offer opportunities for effective interdiction with weapons and associated systems that could be less costly than those required against smaller, more agile targets.

C. LACK OF AN ARCHITECTURAL APPROACH

The term architecture is increasingly, and quite appropriately, applied to the process of designing and acquiring very complex military systems that have elements that are themselves complex systems. An extended-range, smart weapon system, composed of delivery, guidance, munition, sensor, and battle management/C^3 elements, certainly qualifies as a complex system of systems. Besides integrating the several elements into a coherent whole, a systems architecture also provides a roadmap for system evolution: accounting for operational changes, new technology, responsive threats, and evolving mission objectives. In addition, a well-conceived systems architecture approach can help establish research, development, and test priorities; support development of realistic performance requirements and system specifications; and lead to sounder understanding of investment alternatives.

There is little evidence of a coherent architectural approach to smart weapon system acquisition. Indeed, there is just the opposite--evidence of piecemeal, fragmented efforts. There has been some recent progress. Master plans for munitions and standoff weapons are being developed. However, these do not go far enough towards integrating all the elements, not just munitions and weapons, necessary for effective and affordable extended-range, smart weapon systems.

Architecture studies should also include investigation of the role of smarter targeting as a necessary complement to smarter weapons. Requirements for aim point selection and damage assessment must be addressed along with functional failure analysis of target sets (a view of targets as military functions to be disrupted rather than merely things to be destroyed).

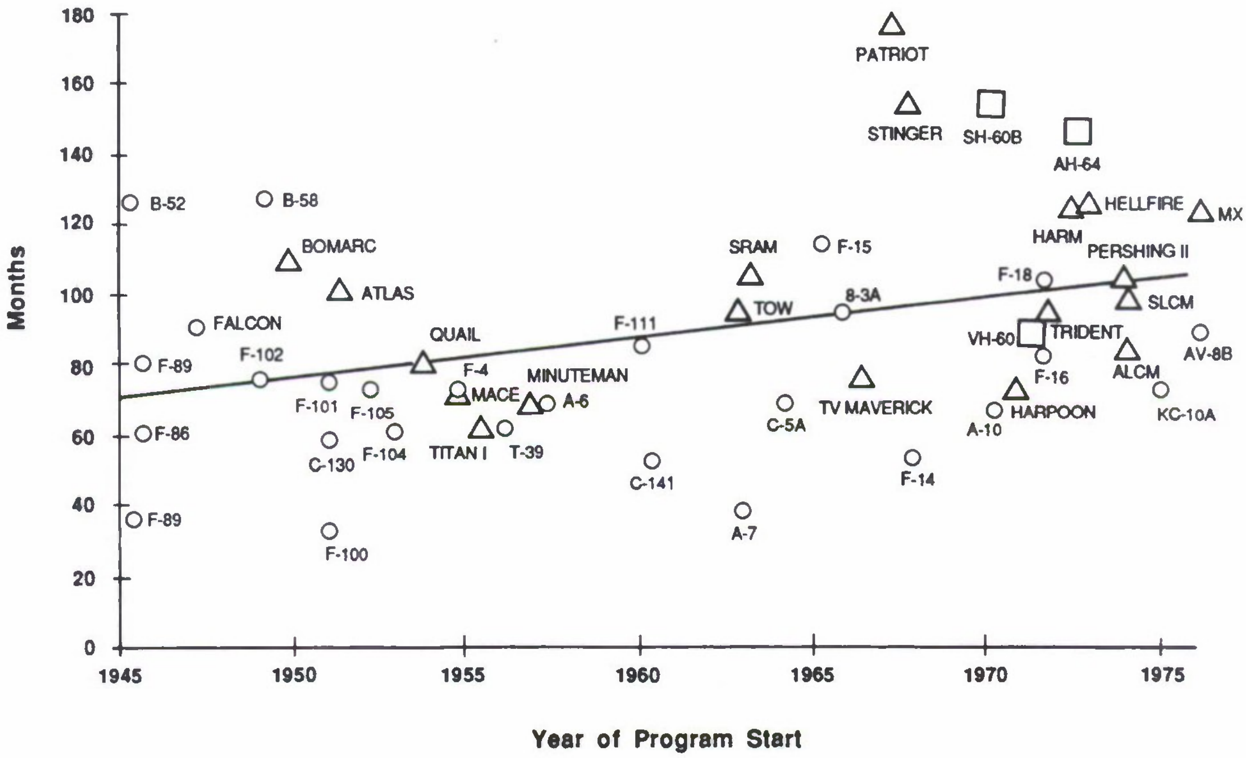
One of the impediments to a coherent architectural approach is that much of the technology and systems are being developed in the highly classified and compartmentalized "black program" world.

D. "BLACK PROGRAM" ACQUISITION MANAGEMENT

It is sometimes argued that weapon systems are taking much longer to acquire, and, thus, the management efficiency of black programs is required. The development time of 49 systems, begun during the period from 1946 to 1976, are shown in the figure on the next page. It shows, for example, that the successful B-52 program took about as long to develop starting in 1946 as the MX took to develop beginning in 1976. The long-term trend toward increased development time shown in the figure is not statistically significant, and can reasonably be attributed to increasing weapon complexity. Furthermore, black programs were not instituted for efficient management control but for protection of critical new technologies and missions. Indeed, many black programs today do not have the lean management structure that often is cited as critical to successful "skunkworks" (the U-2 and SR-71) and "white" (Polaris and Minuteman) programs.

There is a time and a place for black programs, for example, to protect details of sensors that could be exploited by enemy countermeasures. Achieving management efficiency is not a justification for making an acquisition program black.

TIME FROM FIRST MILESTONE TO FIRST DELIVERY



Black program management should be used only sparingly for extended-range weapon system acquisition. Relatively large quantities of weapon systems, supported by a strong technology base and evolutionary product improvement will be needed. Sustaining such a program, particularly in an environment of increasing fiscal constraints, will require a robust political consensus on the value of these systems. Our NATO allies must understand the capabilities of these weapons and also must be prepared to use them. Furthermore, the fundamental objective of the program, deterrence, cannot be fulfilled if potential aggressors lack appreciation of our capabilities.

The large-scale use of black programs is inimical to achieving the necessary political consensus and our objectives of assuring our allies and deterring our adversaries.

E. LACK OF COHERENT INVENTORY ANALYSES

The rather pedestrian phrase "inventory analyses" refers to studies of how many of each type of weapon system we need and why. The normal obstacles to comprehensive and coherent inventory analyses, e.g., intra- and inter-Service rivalries over roles and missions, are compounded by the development of much of the smart weapons technology in the black program world. Thus, capabilities of potentially competing systems are often not known sufficiently by those responsible for doing the analyses. The preponderance of extended-range, smart weapon analyses has been on the micro level, focused on single-weapon/single-target interactions. There have been too few macro analyses to assess overall mission objectives and to relate weapon performance to its complementary surveillance, acquisition, tracking, targeting, and BM/C^3 systems.

The 1985 report of the DSB Task Force on Ground-Attack Munitions cited a lack of adequate inventory analyses as a continuing problem in this area. The Task Force found that existing analyses were "at best ... inadequate, and at worst ... misleading." Regarding the models used to support these analyses, they found that "none of the models are consistent with each other ... and (they) are too complicated to run many sensitivities."

The inability to run sensitivities is especially critical. These models are not predictive; their value lies in providing relative results, i.e., comparisons of alternative performance features, weapons, or tactics.

The situation has not improved markedly since the DSB Task Force's findings 3 years ago. The "win early" concept articulated in the DoD report to Congress on "Support of NATO Strategies in the 1990s" offers a framework to determine affordable and effective stockpile quantities. It provides a rationale for early use of advanced conventional weapons and addresses the issue of the role of our current $70 billion, not-so-advanced munition stockpile. However, catchy slogans do not an analysis make. Indepth, comprehensive analyses of stockpile quantities--accounting for evolution of missions and technologies--remain to be done. Essential for such analyses are credible assessments of the conventional force balance.

Analysts recently have rediscovered the difficulties of assessing the conventional force balance, particularly the inadequacy of "bean counting" and other static measures. (For examples, see the discussion on the conventional forces of NATO and the Warsaw Pact in the International Institute for Strategic Studies publication, The Military Balance, 1987-1988.) The difficulties are manifold. Often what are apparently large differences in force balance assessments are the result of differences in assumptions. Generally, such assumptions, particularly in public discussions, are unstated or submerged. The answers to key questions can lead to significant differences in calculated force balances. Examples of such questions are: What amount of asymmetry between WP and NATO mobilization is plausible? Under what circumstance? Should the French forces be included? What will be the extent of participation by the Soviet Union's East European allies? However, major difficulties and uncertainties remain even after accounting for the differences in assumptions. Many critical factors are extremely difficult to measure. These include not only morale, leadership, and quality of training, but also fundamental battlefield phenomena such as the suppressive effects of indirect fire.

Last, we lack a model that describes the relationships among all the varied and complex factors affecting combat and reliably predicts the outcomes of conflict. This is not due to limitations of current computers; war is and will remain too complex to be captured totally in models. There are too many unknowables, not merely unknowns that can be reduced through investments in intelligence, research, and analysis. Analyzing war or even battle outcomes cannot be reduced to assessing damage to a set of targets. There are no agreed answers to simple questions such as why the front moves at certain rates.

However, in spite of these difficulties we can and must do a much better job in assessing the conventional balance. We need to move away from bean counting and other static measures as a planning tool; their value for selling higher defense budgets is also suspect. Thus, while two-sided dynamic simulations, games, campaign analysis, and other tools have little predictive value, they--aided by expert military and technical judgment--can make substantial contributions to identifying deficiencies and comparing investment alternatives.

F. INSTITUTIONAL INERTIA

While extended-range smart weapon systems may not cause revolutionary changes in warfare to the extent of the crossbow, stirrup, steam, or airplane, neither are they merely improved substitutes for existing capabilities. Exploiting their advantages--including targeting, employment, and deployment flexibility--to the fullest will require changes to force structure, doctrine, and tactics. Therefore, the all-too-familiar culprits--inertia, pedantry, parochialism, and intra- and inter-Service rivalries over roles and missions--must be dealt with.

Increased joint Service planning is a necessary condition for achieving the promise of extended-range, smart weapon systems. The lack of such planning not only leads to research and development inefficiency and redundancy, but to lost opportunities as well. A business-as-usual approach will not generate requirements for technology that may change the way we do business.

G. PLATFORM LOBBIES IN THE PENTAGON

The big ticket platforms--ships, planes, and tanks--have tended to fare better in the Pentagon's internal budget battles than ancillary items such as weapons and munitions. The 1985 DSB Task Force on Ground Attack Munitions examined programming and budgeting trends, and concluded that munitions accounts provide drawing accounts for platform overruns and buffers against outyear budget cuts. Alternative explanations of this phenomenon range from the belief that it represents the correct allocation of our resources to the suspicion that the organization of much of the Pentagon and Services around platforms rather than missions distorts the resource allocation process. The latter claim has considerable merit.

Although the funding for weapons and munitions increased during the mid 1980s, RDT&E funding has subsequently leveled off; procurement funding has decreased; and both face severe competition for future growth (see Appendix B).

H. ARMS CONTROL RESTRICTIONS

The range requirements and capabilities of extended-range, smart conventional weapons force us to rethink previous arms control concepts and language that equate long-range capability to strategic and nuclear roles. Future arms control agreements must make adequate provision for long-range, air-, sea-, and ground-launched conventional standoff weapons. Missile range limits beyond those already imposed by the INF Treaty could significantly reduce the military utility of conventional standoff weapons. Numerical limits could also be crippling, due to the relatively large numbers of conventional weapons required. Distinguishability rules (e.g., nuclear versus conventional) may be essential for preserving our ability to develop needed conventional weapons, but these will be difficult to define, particularly if modularity is pursued as a cost-saving design principle. Similarly, treaty-imposed platform constraints (e.g., a limited heavy bomber force) might reduce the number of attractive launch platforms for extended-range weapons enough to call into question their military effectiveness.

We need to understand much better the risks and benefits of alternative arms control verification regimes, particularly when some of them can restrict important options to improve our conventional force posture.

V. SUMMARY

Extended-range smart weapon systems have the potential to make a major contribution to stopping--and thus deterring--Soviet attacks, not only in NATO's central region, but in Southwest Asia and other areas as well. There are roles for delivery by ground-based launchers, sea-based launchers, and aircraft (both in-theater tactical aircraft and long-range bombers). Ground-launched weapons, e.g., ATACMS and derivatives, would have ranges below the 500 km limit of the INF treaty. Air- and sea-launched systems, some of which could have considerably longer range than 500 km, would provide a capability to respond to short and ambiguous warning attacks worldwide, as well as insurance to hedge against the vulnerability of our in-theater air and ground systems.

In a future where both U.S. and allied military manpower and financial resources may be severely limited, the rapid application of an array of modularly designed standoff weapons could buy valuable time for rapid-deployment air and ground forces to get into place. The long range associated with these systems could aid in the prevention of local enemy concentrations and might be decisive in certain limited conflicts.

Answering the challenge of affordable and effective capabilities will require a mix of weapons with differing characteristics. All the weapons need not have the longest range or the greatest accuracy that may be required for some targets and missions. Nor should all weapons carry identical warheads since munitions designed to destroy bridges are quite different from those designed to attack maneuver battalions. Indeed, by focusing on the most demanding missions, we would price ourselves out of business and end up with relatively few "silver bullets", useful for very specialized operations but hardly relevant in the overall U.S./USSR equation.

The development of extended-range weapon systems should initially focus on fixed and rail targets, and on mobile targets close enough to the FLOT to allow man-in-the-loop target acquisition. These important target sets present fewer technical difficulties and lower cost hurdles than the task of autonomously attacking imprecisely located or moving targets deep in the enemy's rear. Weapon design should be modular: a basic missile compatible with different sensor, guidance, munition, and even range-extension subsystems. A modular, building-block approach, by incorporating new technology--in improved munitions and Automatic Target Recognition and low-cost sensor systems--as pre-planned program improvements, would provide evolutionary growth in effectiveness against a large number of both tactical and strategic targets. It would also provide for component commonality and classification protection of certain critical subsystems.

Technological options are available today that should allow us to develop and manufacture militarily significant quantities of modular standoff weapons. For example, it appears feasible to produce air- and sea-launched weapons for an average unit cost of approximately $500,000 if properly designed for low-cost, high-production volume, and adequate, rather than superb, technical performance. Thus, 10,000 weapons could be produced for an investment of about $5 billion. Similar quantities of ground-launched weapons, with ranges less than 500 km but sufficient to concentrate fire to considerable depth into the enemy rear, could also be produced for several billion dollars. The cost for total system capabilities would be higher, depending on the surveillance, damage assessment, and BM/C^3 requirements. These costs are far from trivial; however, they could be manageable if there is anything at all to the promise of smart weapons.

The U.S. cannot depend on maintaining leads in all relevant technologies. Likewise, we cannot depend on preserving monopolies in certain types of systems. Thus, the Soviets will eventually have stealthy aircraft and missiles, just as they are developing smart weapons. However, some technologies may favor us even if we do not maintain a significant lead, either because we can use them to exploit some special characteristic or tactic of our adversary (the case for FOFA rests somewhat on arguments regarding Soviet-style echelonment and reinforcement) or because they intrinsically favor the defender over the attacker. The keys to competitive strategy success are to identify the technologies and implement the capabilities that will exploit these enduring Soviet weaknesses and U.S. strengths. Extended-range weapon systems are among the most promising of these technologies and capabilities.

VI. RECOMMENDATIONS

These recommendations, in the form of one don't and three do's, are aimed at overcoming some of the formidable obstacles and shortcomings discussed previously. The don't is intended to preserve options, the do's to generate the data and establish the framework necessary for a coherent program over the long term. They do not address specific concepts or systems, or particular near-term budget issues. With one exception, the recommendations do not require significant expenditures of funds.

1. To all those responsible for U.S. arms control policy and negotiations: Avoid further constraints on extended-range conventional weapon options imposed by arms control agreements unless comprehensive and credible analyses demonstrate that such constraints are in our best interest in the long run. Making verification easier should not be sufficient justification to impose constraints.

2. To the Office of the Secretary of Defense (OSD) and the Services: Enlarge efforts to test smart weapon systems in environments relevant to the modern battlefield. The Chicken Little tests are a good start. However, given the long-term importance of smart weapons and the uncertainty regarding their performance in war, it is not excessive to establish a National Test Bed as the focus of this activity. Whatever the title, we need a capability to systematically, comprehensively, and objectively evaluate alternative technologies, concepts, systems, and tactics, accounting for the fog and noise of war as well as enemy countermeasures. The test capability should allow for man, hardware, and simulation in the loop. It should complement other capabilities, such as the National Training Center and SIMNET, the combined arms simulator network, (which

could be particularly useful in examining the cross-corps role of extended-range weapon systems). These capabilities, established primarily for training, have the potential, as yet untapped, to contribute substantially to the acquisition process.

3. To the Joint Chiefs of Staff, Office of the Secretary of Defense, Unified Commands, and the Services: Conduct comprehensive studies of inventory requirements and investment alternatives. These studies are needed early in the development process, for they will influence performance specifications. The studies should consider the several theaters of interest, not just NATO's central region. The Unified Commands should play a leading role in developing appropriate target sets within the context of plausible contingencies in their regions of responsibility.

The studies should address synergisms and trade-offs among the several battlefield missions (close, near, and deep battles), multiple delivery means (land-, air-, and sea-launched), and classes of weapons (short and long range, dumb and not so dumb). An important consideration is the implication of our having a mix of stealthy and non-stealthy platforms, a situation likely to exist for a long time. The studies should also examine roles for our allies and transcend the Services' roles and missions parochialism by investigating new doctrines and tactics that can exploit the capabilities of these new technologies.

A prerequisite to the inventory analysis is the development of objective and comprehensive net assessments of the conventional force balance. Such assessments can help provide the foundation for our defense investments. The assessments, therefore, should be credible to professional military and defense specialists and understandable to the non-specialists. Exaggerating asymmetries discourages serious efforts to improve our posture. As one defense analyst remarked only slightly cynically: we have lost our ability to keep two sets of threat books--one to sell programs, the other to guide our real planning.

4. To the Services, Joint Chiefs of Staff, Office of the Secretary of Defense, and the Defense Advanced Research Projects Agency: Treat extended-range weapon systems as complex systems of systems and develop evolutionary architectures to guide the design and acquisition of these systems. The approach should include a long-term research and development commitment and an acquisition strategy covering: operational considerations; mission planning and targeting requirements; unitary and submunition warheads (including air-deliverable smart mines and penetrating warheads); low-cost sensor systems; Automatic Target Recognition algorithms; low-cost, modular weapon design and manufacturing techniques; battle management/C^3; and surveillance and damage assessment systems. It is essential that our allies participate in these architecture endeavors.

   This may be the most important recommendation. It surely is the most difficult to implement. Our acquisition system is not conducive to comprehensive system-of-system architecture approaches. Congress's penchant for micromanagement and tendency to focus on the leaves rather than the forest are major impediments. Even within the Pentagon, too many committees, steering groups, and the like appear to be largely adversarial, concerned with oversight or competition for resources. Too few engender the spirit of cooperative problem-solving needed to conceive, nurture, and implement complex system architectures.

The close coupling between extended-range weapon systems and other elements of our conventional forces makes assigning architecture responsibility to a dedicated OSD office difficult; thus, the Strategic Defense Initiative Office is not the appropriate organizational role model. There is a role, however, for a strong OSD focal point to orchestrate the responsibilities now scattered among several offices. Multi-Service program offices can also have value. Establishment of an Executive Committee of the principal Service and OSD players, to bring together the diverse elements and foster a coherent structure, is another step that may help. However, it could merely add another layer of valueless overhead. Organizational fixes are secondary to having a high-level sustained commitment to doing it right.

APPENDIX A. ILLUSTRATIVE TARGETING REQUIREMENTS

The type, number, character, hardness, and military utility of Warsaw Pact targets vary. It is beyond the scope of this study to perform the detailed analyses necessary to determine the preferred weapon mix and allocation to targets. Tables A.1 and A.2 on the following pages show an illustrative sample of targets by class, weapon range, and required weapon accuracy for two theaters of operation (central Europe and Southwest Asia).

In this exemplar analysis, over 8,000 weapons are used to cover fixed targets in central Europe (see Figures A.1 and A.2 for typical areas covered). Another 26,000 weapons attack mobile targets in central Europe. Additionally, almost 1,400 weapons are employed in a hypothetical Southwest Asia contingency. The capabilities offered by ships and long-range bombers like the B-52 for timely response to contingencies in many theaters argue that a significant portion of these weapons be identified for delivery from airborne and sea-based platforms.

Obviously, the overall force requirements could vary considerably, depending on the assumptions made about damage requirements, employment concepts, and other factors. Key assumptions implicit in the force-level estimates shown here are included in the two tables. Note that several classes of targets require re-attacks. Note also the large force postulated for attacking mobile targets. In practice, that number might be reduced substantially if other forces (e.g., tactical aircraft) were allocated to a portion of these targets, if smart air-delivered mine munitions were developed, if some portion of the target set were considered too difficult to attack (and, therefore, not worth buying weapons to attack), or if lower levels of damage or target coverage were considered acceptable. On the other hand, these force levels could increase considerably --or expected damage could drop substantially--if surveillance, discrimination, or battle management/C^3 proved inadequate.

TABLE A.1: TARGETING REQUIREMENTS FOR CONVENTIONAL STANDOFF WEAPONS

TARGET CLASS	TARGET CHARACTERIZATION	NUMBER OF TARGETS WITHIN MISSILE RANGE (FIGURES A.1 & A.2)		NUMBER OF TARGETS ATTACKED[1]		TOTAL NUMBER OF WEAPONS EMPLOYED WITH RANGE LESS THAN[2]	
		600 km	1,400 km	600 km	1,400 km	600 km	1,400 km
A. EUROPEAN THEATER							
Fixed Targets							
Major Airfields	Runways	150	300	20	30	540	810
Railroad Bridges	Point	250	400	80	130	2,400 (1,200)[3]	3,900 (1,950)
Key Highway Bridges	Point	300	450	90	130	1,350 (540)	1,950 (780)
Tactical Command Bunkers	Point	300	?	300	300	1,500	1,500
POL Pumping Station	Area/Multiple Point	20	70	10	30	100	300
TOTAL (Fixed)		**1,020**	**≥1,220**	**500**	**620**	**5,890**	**8,460**
Mobile Targets							
Maneuver Units (Artillery and Maneuver Battalions)		1,700	1,700	1,700	1,700	22,000	22,000
Mobile Missiles		700	800	700	800	3,800 (1,520)	4,200 (1,660)
TOTAL (Mobile)		**2,400**	**2,500**	**2,400**	**2,500**	**25,800**	**26,200**
TOTAL (Fixed and Mobile)		**3,420**	**3,720**	**2,900**	**3,120**	**31,690 (27,400)**	**34,660 (29,000)**
B. SOUTHWEST ASIA - EXAMPLE: IRAN							
Airfield Runways		–	6	–	6	–	162
Highway		–	80	–	80	–	1,200
TOTAL			**86**		**86**		**1,362**

[1] Authors' assumptions, based on prior investigations.

[2] Assumes a 1,000 lb. unitary warhead with a 3-meter CEP or, if appropriate, an equivalent load of submunitions; system reliability = 80%; system survivability = 80%; system availability = 95%; confidence of destruction = 80%.

[3] The lower number of weapons displayed within parentheses assume a 1-meter CEP weapon.

The feasibility and cost-effectiveness of employing these systems against many mobile targets depends critically on developing survivable surveillance and C^3I systems. Attacks on the Warsaw Pact rail system is a notable exception to this concern and would make less demand on surveillance and C^3I capabilities.

The longer range weapons could be especially important early in the conflict. As enemy defenses are suppressed, later stages of conflict may rely more heavily on short- to intermediate-range weapons. An important use of these weapons--as discussed in chapter II--is to concentrate firepower in space and time to counter the concentration of offensive forces. Most of these weapons could have ranges considerably less than 600 km: from 100 km to a few hundred kilometers. Their targets would be fixed (bridges), mobile (SAMs or C^3 sites), and moving (troops, armor, or self-propelled artillery in road march). Again, locating these targets and timing the attacks would put heavy demands on our surveillance and C^3I capabilities. Comprehensive inventory analyses and architectural studies are needed to help develop and sustain the proper DoD investment strategy.

TABLE A.2: ASSUMPTIONS ABOUT TARGETING AND WEAPON ALLOCATION

Target Type	Number of Weapons/Target[1]	Number of Attacks/Target
Airfield Runways	9	3
Railroad Bridges	10(5)/aimpoint	3
Highway Bridges	5(2)/aimpoint	3
POL Pumping Stations	10(3)/aimpoint	1
Maneuver Units and Artillery Battalions	5/unit or battalion	3
Mobile Missile Launchers	5(2)/launcher	2

[1] Assumes a 3-meter CEP; the lower number (in parentheses) would be required if a 1-meter CEP weapon were available.

FIGURE A.1: EUROPEAN TARGET COVERAGE OF A STANDOFF MISSILE WITH 600 KM RANGE (notional northern and southern launch points)

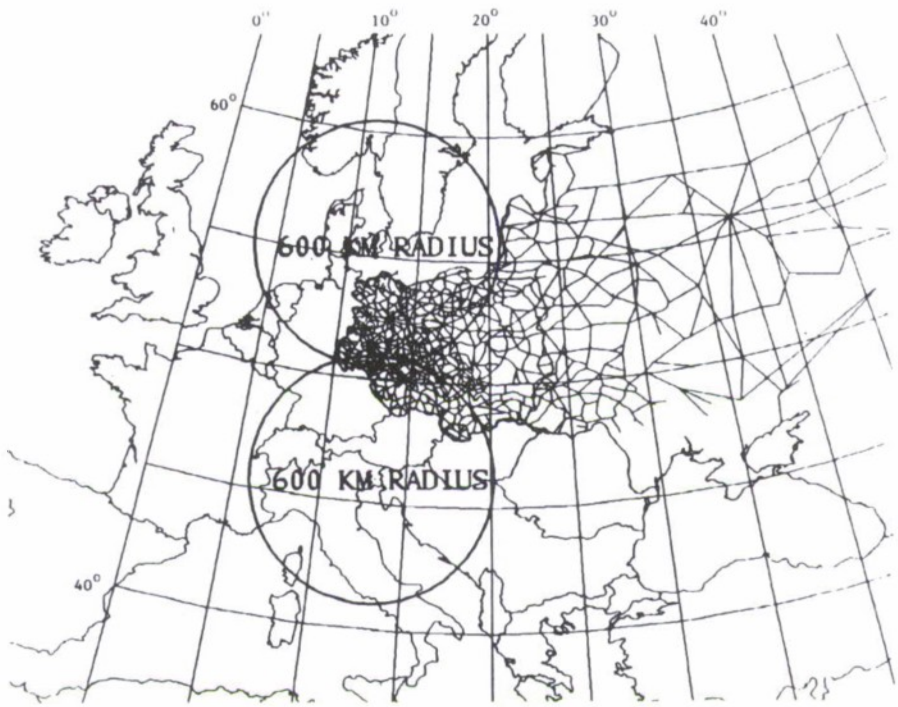
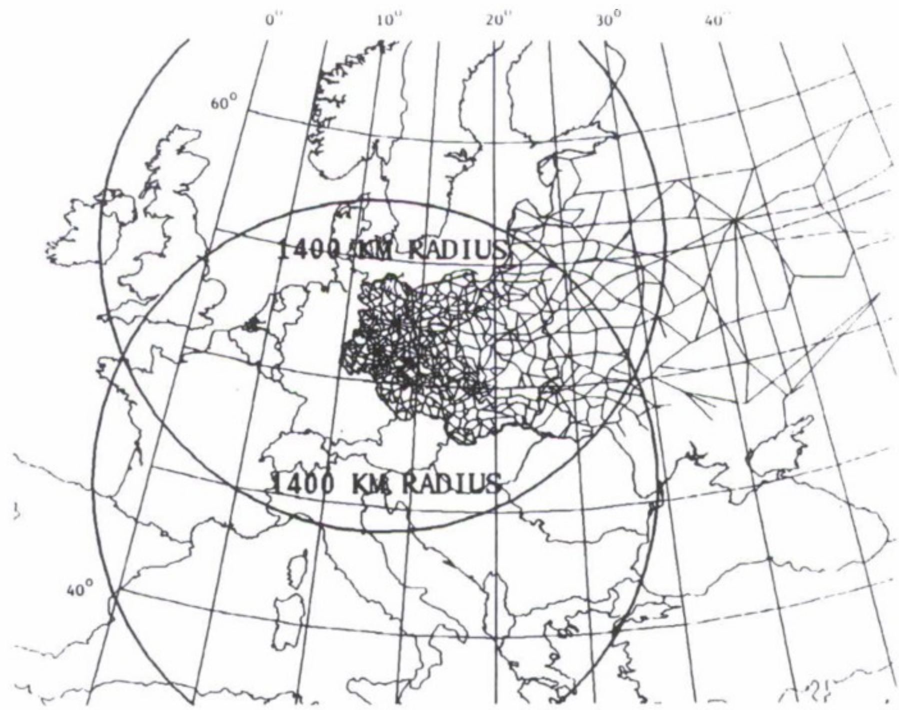


FIGURE A.2: EUROPEAN TARGET COVERAGE OF A STANDOFF MISSILE WITH 1400 KM RANGE (notional northern and southern launch points)



APPENDIX B. FUNDING TRENDS FOR MUNITIONS

The annual funding for Research, Development, Test, and Evaluation (RDT&E) of conventional munitions since FY 1984 are shown in Figures B.1 and B.2. Included are funds for ammunition, bombs, torpedoes, rockets, missiles, other weapons, and related technology programs. Figure B.1 displays the trends for all munitions and for two subsets: all smart munitions and smart, ground-attack munitions. The funding for smart munitions is shown again in Figure B.2, along with the funding for all DoD RDT&E.

FIGURE B.1: FUNDING FOR MUNITION RDT&E

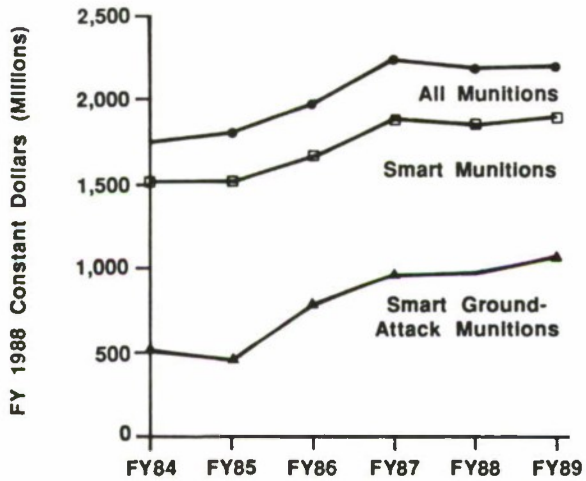
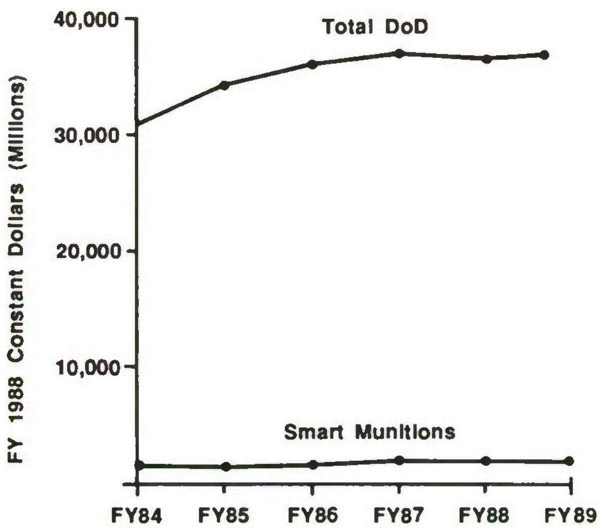


FIGURE B.2: DoD RDT&E FUNDING



The 1985 DSB Task Force on Ground-Attack Munitions examined the funding history for munitions prior to 1984. Their report observed that the munitions DT&E funding declined, not only as a percent of the total DT&E during the budget growth years of the early 1980s, but in constant dollars as well. As shown in the figures, RDT&E support for munitions, particularly ground-attack munitions, has been somewhat stronger since 1984. However, the increases of 1986 and 1987 were not sustained, and funding leveled off as the budget pressures tightened. The smart munitions share of the total DoD RDT&E budget has remained at approximately 5 percent during this period.

Funds for procurement of weapons, Figures B.3 and B.4, show a more dramatic discontinuity than the RDT&E trends: the funding declined in FY 1986 and still is below the levels of the mid 1980s. However, the percent of total DoD procurement funds devoted to smart munitions has risen since 1984, from less than 6 to almost 9 percent.

FIGURE B.3: FUNDING FOR MUNITIONS PROCUREMENT

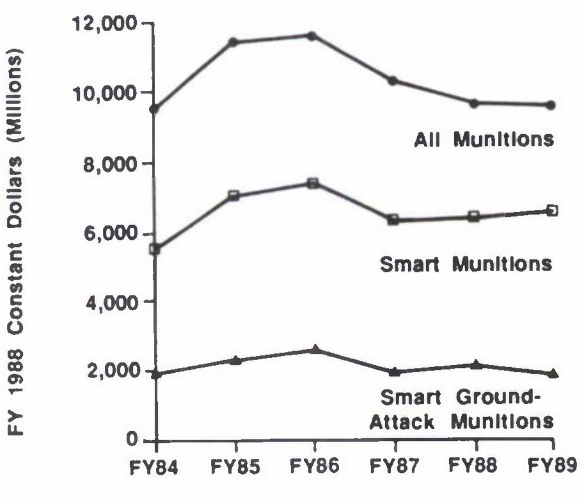
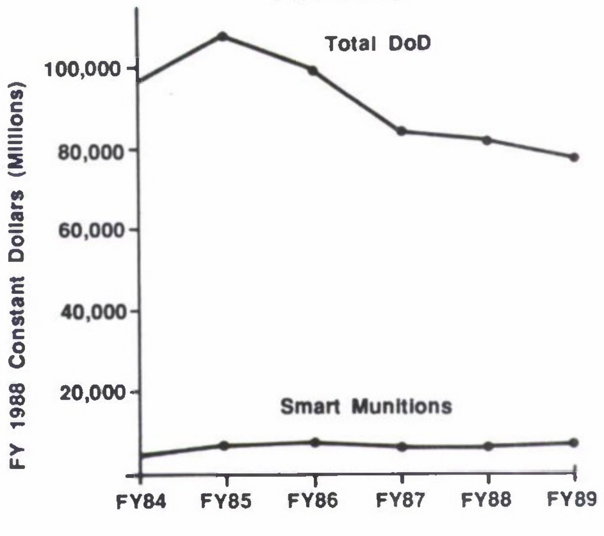


FIGURE B.4: DoD PROCUREMENT FUNDING



Figures B.5 and B.6 show that while procurement funds for extended-range, ground-attack munitions have increased since 1984, the funding for extended-range, ground-attack munitions remains a relatively small part of the funding for all ground-attack munitions.

FIGURE B.5: FUNDING FOR GROUND-ATTACK MUNITIONS RDT&E

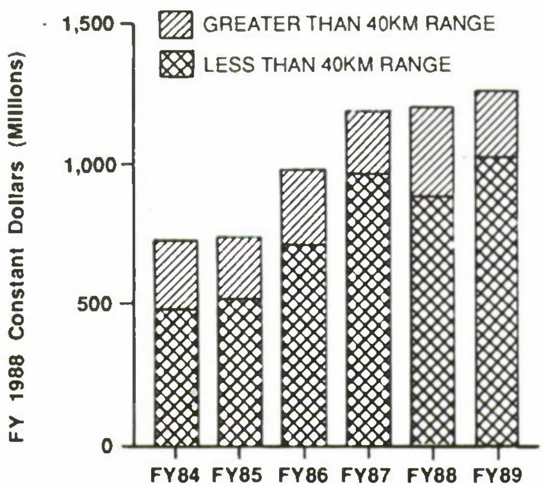
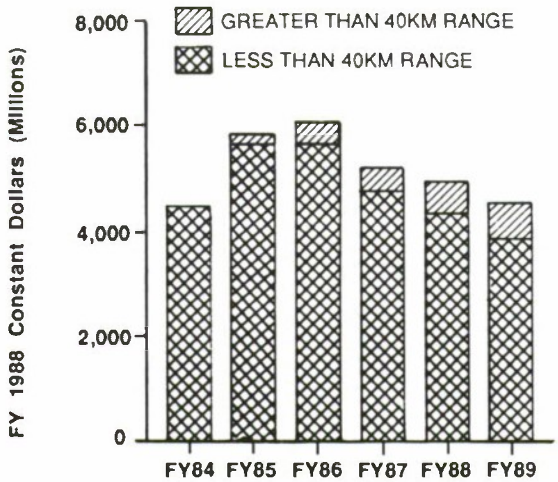


FIGURE B.6: FUNDING FOR GROUND-ATTACK MUNITIONS PROCUREMENT



The figures in this appendix provide only a rough guide to trends. They do not include funds for classified programs nor complementary functions such as surveillance and C^3.