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WEAPONS, PLATFORMS, AND THE NEW ARMED SERVICES

Seymour J. Deitchman

PROLOGUE: *Advances in electronics and other fields since V*
have made possible the so-called smart weapons—guided wea
home on targets—as well as new systems for finding and identifying those targets. This advanced technology is controversial, precisely because it lies at the heart of the debates on cost-effective defense and modernization of the armed forces.

Advocates of this advanced technology say the military is not using it either well or fully. They claim that the new guided weapons can be fired with greater accuracy, from longer (and thus safer) distances, than their unguided predecessors. Adherents of this view in the defense community and Congress argue that the full development and deployment of guided weapons and other advanced defense systems can make possible more effective and less costly military forces. Moreover, they maintain, the quality of this military technology can offset our disadvantage in the face of a much larger Soviet threat, allowing the United States to substitute accurate firepower for manpower, tanks, and aircraft.

HIGH TECHNOLOGY AND DEFENSE: HOW LARGE A ROLE?

Cris Schall, Editor

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On the other side, the defense reform school maintains that we are deluding ourselves—that many of the sophisticated and expensive new systems will simply not work as advertised on the battlefield. As a result, the military is acquiring weapons that are too expensive, difficult to use, and prone to failure. Equally important, they say, the promise of advanced technology has diverted attention and funds from building up the size of our own forces and from acquiring reliable systems that are known to work in combat.

In this article Seymour J. Deitchman of the Institute for Defense Analyses (IDA) argues that guided weapons and electronic systems are becoming the real basis of military power. However, the military services continue to focus their attentions and budgets mainly on improving the platforms—the ships, tanks, and aircraft—that carry and launch the weapons. Shifting necessary funds from platforms to guided weapons will not save money, as some proponents claim; nor will it be easy to overcome institutional resistance to change, Deitchman says. But unless we do so, he concludes, the United States will sacrifice an opportunity to achieve an enduring military superiority.

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TECHNOLOGY AND DEFENSE: WEAPONS VERSUS PLATFORMS

We are in the midst of a period of revolutionary change in the technology of the general purpose military forces—essentially all of our military forces other than the intercontinental nuclear forces. Over the next decade or two, those forces will be transformed radically in their doctrines, modes of operation, and capabilities. If we control the process of change appropriately, our forces are likely to become the most effective in history. If we fail to face the full implications of these changes, our forces will not be effective enough to fight in the new ways or large enough to fight in the old ways.

The revolution in military affairs is driven by the same technological advances that are making startling changes in the civilian world. These advances include mainly the application of solid-state electronics to computation, sensing, guidance, communication, and control of all manner of devices and machines. These advances also include the application of advanced materials to structures and propulsion systems that allow aircraft to fly farther, faster, higher, and to carry heavier loads; that allow ships to endure almost indefinitely at sea; and that make tanks and other armored fighting vehicles far tougher to destroy than they were even a dozen years ago.

When the President wants to signal our allies and adversaries that he is increasing military strength, he first buys platforms.

The impact of these technological advances on military power may be characterized rather simply. Relative to the past, it is becoming easier to observe where enemy forces are and what they are doing, and to interfere with their ability to observe our forces. We are also gaining the ability to fire guided weapons that can hit targets with far higher probability than could the unguided weapons used in the past. (Those were fired with little expectation that individual rounds would hit—but with full expectation that the mass of ammunition would eventually do enormous damage to enemy forces.) If fully absorbed by the armed forces, these technological advances will permit vastly greater "economy of force" in military operations: it will be possible to use forces of modest size much more effectively, at points where their effectiveness counts the most.

In the process, systems for command, control, and communication; surveillance; and target acquisition—which used to be considered support systems—have become as important and expensive as the ships, aircraft, and armored fighting vehicles that have defined the military services since World War II. Guided weapons, too, have become expensive enough to compete with aircraft, ships, and tanks for a share of military acquisition budgets. Stated simply, guided weapons and the associated electronic systems have increased in military importance and cost relative to the platforms that carry and launch them. These systems are coming, in many respects, to usurp the platforms' claim to be the real basis of military power.

Nonetheless, there are powerful incentives to continue in the old, familiar directions. When the President wants to signal our allies and adversaries that he is increasing military strength in the general purpose forces, he first buys platforms—and only if resources remain in the total budget does he buy more effective weapons or more effective command and control systems.

In this article I will review the new military capabilities that advanced technology makes possible, and then will examine the forces that determine both the speed and direction in which new technology is integrated into the armed forces. Specifically, I will explore the pressures of international competition that push for change and the institutional biases that work against it. And finally, I will suggest ways in which the armed forces can adapt to ensure their continued strength in the face of increasingly capable adversaries.

II

This country came out of World War II with a strong commitment to using tactical aviation, whether land-based or seaborne, to support our international commitments. Except for the ground forces it was necessary to retain in Europe, first as an army of occupation and then as part of the North Atlantic Treaty Organization, the tendency since World War II has been to reduce the size of our ground forces while maintaining our tactical air and naval strength—the latter primarily as a means of moving tactical aviation to areas not accessible from land bases. (Although the Army was built up during both Korea and Vietnam, it declined in size subsequent to each conflict.) Tactical air and naval forces gave us the ability to deploy significant military power rapidly to various parts of the world in defense of our interests and those of the alliances we forged in the decade following World War II.

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The technical basis of our military power has been transformed radically since World War II. By the end of that war, radar and sonar were maturing, and these capabilities were soon augmented by sensing in the infrared region. The war also saw the beginning of guided weapons. These were subsequently developed for uses in which targets could be distinguished from background with relative ease (as in air-to-air, surface-to-air, and anti-ship missiles) or in which a gunner with a command link to this weapon could keep his target in view (as in wire-guided anti-tank missiles). Now self-contained guidance techniques are beginning to be applied in the most difficult area—where background clutter interferes with the sensors' ability to "understand" target signatures, as in air-to-ground or "fire and forget" ground-to-ground weapons. These efforts will form the basis of future guided-weapons capability.

Paralleling the growth of radar and infrared sensing has been the vast increase in the diversity, flexibility, and complexity of communications and information processing. With the sensors, these advances are the basis for today's sophisticated command, control, communications, surveillance, and target acquisition systems. Advances in these areas will continue to enhance our ability to know where the enemy is and what he is doing (but not necessarily what he *intends* to do). Needless to say, the development of such capabilities has also engendered advances in electronic warfare, such as jamming, listening, and other means of masking or exploiting electronic signals.

The advent of jet aircraft greatly expanded the distances that could be covered by land-based and seaborne tactical aviation and increased its fighting power. Jet aircraft also enhanced the mobility of our strategic forces. With jet aircraft also began the trend, now evident in all war machines from tanks and airplanes to aircraft carriers, to consolidate "overhead" functions by aggregating weapon loads into fewer, more capable platforms. Thus, combat aircraft (other than bombers) have grown from a gross weight of roughly 5,000 to

10,000 pounds in the 1950s to between 50,000 and 100,000 pounds today, and aircraft carriers have grown from 30,000 to 90,000 tons or more. The resulting forces are stronger overall, but the consequences of losing a single aircraft or ship are far greater because there are fewer of them.

Other advances in propulsion led to nuclear power, which converted the submarine navy to a true undersea fighting force that for all practical purposes is as fast underwater as a force of surface ships and is in most circumstances less vulnerable to detection and attack than its World War II predecessor. Solid rockets and small jet engines have increased the range of guided missiles, which may now cover distances of hundreds of miles when surface-launched over the battlefield, tens to thousands of miles when air launched, and, of course, intercontinental distances in strategic warfare.

The same advances in electronics that have led to remote sensing and guidance also permit remote control of aircraft. Equipped with sensors and munitions, remotely piloted vehicles can replace manned aircraft in dangerous environments. Spacecraft now support many auxiliary military functions, including observation, surveillance, communication, and navigation.

Finally, the advances in guidance for weapons designed to attack targets on the ground will make possible missiles equipped with specialized and effective conventional explosive munitions. These may include terminally guided submunitions that can seek and destroy vehicles, small bombs that can penetrate and heave up large areas of concrete runways, and small mines that can be scattered to greatly complicate operations on airfields or on battlefields. In the future multiple munitions of this kind could be incorporated into ballistic missiles, making them economical and effective for conventional warfare. (Heretofore, ballistic missiles have been used mainly for nuclear and chemical warfare.) These advanced guided warheads could also be incorporated into air-launched missiles having longer ranges than those that exist today. These missiles would permit the launching aircraft to stand away from heavy defenses in the immediate target areas while the missiles attack the targets.

III

All these advances will continue to have profound implications for the capabilities of military forces and how they fight. The improvements in sensing, electronic warfare, and command, control, and communications bring the "information war" to the forefront. The attempt to gain an information advantage by observing the other side's forces and activities while denying them such information about one's own forces becomes a primary rather than an ancillary part of direct conflict. Because the numbers of fighting units in the West's armies and air forces have declined, it is essential that the fewer and smaller units be able to move fast to bring military power to bear in the right place at the right time. The information advantage can make this possible. However, the growing costs of information gathering and of guided weaponry heighten the need to integrate the military forces beyond the degree necessary even two decades ago. The field commander must orchestrate the operations of land, air, and sea forces, without being hampered by incompatible systems that inhibit the effective and timely coordination of the forces' activities. Moreover, the services can use compatible systems, since the same basic technology finds and attacks targets and controls forces in much the same way whether it is used by air, land, or sea forces.

The growing use of guided weapons by both sides, together with enhanced target acquisition abilities, increases the rate of attrition of force units—aircraft, tanks, ships, cannon, and so forth. Thus, to extend their combat lifetimes, aircraft, ships, or tanks will have to "stand off" from well-defended targets by using longer-range missiles. The use of these missiles increases the complexity and cost of systems needed to find, identify, and locate targets, and to coordinate combat activity.

Ultimately, the weapons and other electronic systems, rather than the launching systems, define the fight. Aircraft and even tanks do not need sophistication to carry the target acquisition systems and to deliver the long-range weapons; they need it only to keep from being destroyed by the other side. If standoff guided missiles can keep platforms out of enemy reach, the platforms' sophistication becomes far less important. As the costs of the "target engagement" systems increase, they compete with platforms for available funds, raising the question of how much capability must be built into the platform when the weapon and electronic systems do most of the work.

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New platforms can increase the mobility and survivability of weapon systems. But with the advances in weapons, the platforms that deliver them do not have to be replaced as often as in the past. When we do renew them, we can take advantage of new technical opportunities, such as vertical takeoff and landing for aircraft. In addition, advanced weapons technology allows older platforms to be used in new ways. For example, an aircraft like the F-4, originally designed to shoot down the enemy or drop bombs at close range, can be given the ability to shoot at targets from much longer range by using on-board improved radar and missiles, and by having an airborne radar system, such as AWACS, guide it to its missile launch points. The useful life of the F-4, which has become obsolescent, would be extended, perhaps for a long time. Cruise missiles that can travel 200 or 300 miles to attack bridges, airfields, and other fixed targets can be launched by transport or patrol aircraft as well as by the bombers or fighter-bombers used now. Similarly, since the performance of anti-aircraft and anti-ship missiles is indifferent to what type of aircraft and which service launches them, patrol aircraft, bombers, and interceptors could be used to protect aircraft carriers at sea. Thus, carriers would not be diverted from their attack missions by the need to protect themselves.

To appreciate the impact of these technological changes on the general purpose forces, we might note that a U.S. armored division or tactical fighter wing today can destroy up to 10 times as many targets in similar opposing formations as could their counterparts of the Korean War era—depending, of course, on the terrain, weather, and opposition. With modern sealift and airlift, using such carriers as the C-5 cargo plane, the first divisions and fighter wings can now deploy from their bases in the United States to Europe, the Middle East, or the Far East in one-half to one-quarter of the time that it took to bring effective forces to bear in the Pusan perimeter at the outset of the Korean War.

Full deployment and integration of the emerging weapons and tools of warfare into the armed forces would have similar or greater effects on combat power over the next decade or two. The gains in fighting power would mean that smaller forces could establish an even more effective combat presence at distant sites in even shorter times than are possible today.

Until recently, the military gains were derived mainly from advances in platform technology, such as advanced aircraft, ships, and armored fighting vehicles (with an assist from some areas of weaponry and from surveillance and command and control systems). By contrast, the greatest military gains of the future will come from guided weapons and electronic systems for sensing,

TABLE 1: MAJOR PLATFORMS, WEAPONS, AND COMBAT SUPPORT SYSTEMS AND THEIR TOTAL ACQUISITION COSTS*

PLATFORMS *(Aircraft, Ships, Fighting Vehicles)*		
AH-64 Attack Helicopter	*(Army)*	$ 7.2 Billion
F-14 Fighter/Interceptor	*(Navy)*	$42.9
F-15 Fighter	*(Air Force)*	$39.1
F-16 Fighter	*(Air Force)*	$44.0
F/A-18 Fighter/Attack	*(Navy)*	$32.2
AV-8B Vertical Takeoff Attack	*(Marine Corps)*	$ 9.4
CG-47 Fleet Air Defense (AEGIS) Cruiser		$25.0
DDG-51 General Purpose Destroyer		$11.1
M-1 Tank		$17.2
M-2/M-3 Armored Fighting Vehicle		$ 9.9
WEAPONS *(Guided)*		
COPPERHEAD Guided Artillery Shell	*(Army)*	$ 1.6
HELLFIRE Anti-Tank Missile	*(Army)*	$ 2.3
HARPOON Anti-Ship Missile	*(Navy)*	$ 4.9
HARM Anti-SAM Radiation-Seeking Missile	*(Navy, Air Force)*	$ 5.7
AMRAAM Advanced Medium Range Air-to-Air Missile	*(Air Force, Navy)*	$ 8.3
MAVERICK Infrared Air-to-Ground Anti-Armor Missile	*(Air Force)*	$ 4.9
PAVEWAY-II Laser-Guided Bomb	*(Air Force)*	$ 1.8
TOMAHAWK Long Range Conventional Cruise Missile	*(Navy)*	$11.3
COMBAT SUPPORT SYSTEMS *(includes carrying vehicles where appropriate)*		
AWACS Airborne Warning and Control System	*(Air Force)*	$ 7.6
EF-111A Airborne Electronic Warfare System	*(Air Force)*	$ 1.9
KC-10A Tanker Aircraft	*(Air Force)*	$ 4.4
JTIDS Joint Tactical Information Distribution System	*(Tri-Service)*	$ 4.4
NAVSTAR Satellite Navigation System	*(General Use)*	$ 2.5

**Corrected to FY 1985 dollars, billions. Includes development and procurement costs and total planned numbers in acquisition.*

Source: Department of Defense Selected Acquisition Reports to Congress, Dec. 31, 1983 (most recent). Data compiled by J. Stahl, Institute for Defense Analyses.

information processing, communication, and control. (In inversion of earlier developments, however, advances in platform technology will be helpful in enhancing the utility of the weapon systems.) As long as most of our efforts were concentrated on improving platforms, our European allies and the

Soviet Union have been able to keep pace with U.S. capabilities. However, the United States has a much more commanding lead in electronics over both its friendly competitors and its adversaries than it has in platform technologies. We should therefore be able to achieve a technical military superiority in the future greater than we ever have, and to sustain it over a longer time.

However, as a nation we have not yet decided whether to shift enough emphasis from the platforms to the weapons to achieve the full potential of the new technology. By giving priority to the new platforms and then trying to augment the remaining resources for acquiring weapons and electronic systems, we are supporting neither weapons nor platforms as well or as fully as we might. If we make the wrong choices (as judged by history, not by contemporary critics), we will have sacrificed a potentially long period of qualitative dominance in military capability.

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IV

The adaptation of the armed forces to technological change is conditioned by a number of factors. International competition presses for change; cost restrains it; and institutional factors in the armed forces and society at large channel it in certain directions or inhibit it altogether.

The most important external factor is the increasing military power of the Soviet Union. The Soviet Union has developed its military forces differently from ours. As a land power with central lines of communication, the Soviets have relied heavily on large ground forces. Since modern ground forces are built around tanks and other armored vehicles, Soviet and Warsaw Pact holdings of such equipment have come to outnumber ours and those of our NATO allies by a factor of three, four, or more, making it appear increasingly difficult to defend Western Europe without resorting to nuclear weapons.[1] Knowing the power of Western tactical air forces, the Soviets have built a system of mobile air defenses, including interceptor aircraft and surface-to-air missiles. While individually inferior to similar Western systems, the Soviet interceptor aircraft and surface-to-air missiles exist in sufficient number to constitute an increasingly powerful defense against tactical aviation. This is threatening to the West, as tactical aviation is a major element of NATO's ability to respond to an attack by Soviet armored forces. Finally, facing a large surface navy with effective defenses against aircraft, close-in ships, and submarines, the Soviet Union took the lead in building a large variety of cruise missiles to attack that navy. The United States and NATO countries are only now beginning to deploy significant numbers of anti-ship missiles, in response to the buildup of the Soviet surface navy.

The Soviets also rely much more than the West on ballistic missiles—both nuclear and conventionally armed tactical ones—for battlefield use. This results in part from doctrines that treat nuclear and conventional weapons in a much more integrated fashion than we do. As noted earlier, the economics of ballistic missiles for conventional warfare may come to look quite different to the United States and its allies as specialized and guided submunitions for such missiles become effective and practical. Until that happens, however, the missiles give the Soviet Union a certain advantage because they are harder to defend against than aircraft alone would be.

Given the growth of Soviet military capabilities, the United States must enhance its own forces if they are to retain their deterrent value. Basically, deterrence in the general purpose forces implies the ability to fight opposing forces and win. However, the United States and its allies have come to rely heavily on the *politics* of deterrence in building their military forces. In other words, there has been a blurring of the boundary between how much conventional military force it takes to "win" a war and how much it takes to simply discourage an attack. Thus, "how much is enough" has become more a matter of political than military judgment. This politics of deterrence encourages a reluctance to come to terms with the cost of effective conventional war-fighting capabilities, since force sizes can be adjusted to desirable budgets and rationalized by notions of deterrence that cannot be tested.

Soviet military strength is not the only factor driving the advance of military technology. The growth and importance of the defense industry in the economies of the United States and its major European allies has translated into de facto economic rivalry, despite the urge to cooperate. The undesirable effects of this competition are seen in the inefficiencies of procurement and operation within the Atlantic alliance—for example, redundant acquisitions of tanks or fighter aircraft, the inability of one country's support systems to service those of another, or unwarranted duplication of logistics lines and facilities. Of much greater concern, however, is the increasing spiral of sales of sophisticated technology to Third World countries, which this economic competition with our allies encourages.

The transfer of modern weaponry to the Third World enables the Soviet Union to gain access to our advanced technology more easily. Also, the industrialized nations must be more circumspect in advancing and protecting their interests in the Third World—even aside from possible Soviet intervention—than was the case in the days immediately after World War II. And as advanced military technology spreads to our potential adversaries, the United States must increase the rate of its own technological advance.

Cost, however, will restrict that rate of advance. The costs of military technology do not depend on military factors alone. They are also affected by the growing application of advanced technology, especially solid-state electronics, in the commercial sectors of the United States, Europe, and the Far East. For example, in the early 1960s the military constituted virtually the entire market for such electronic circuitry in the United States, yet by the mid-1970s defense applications accounted for only about 10 percent of that market. Similarly, the use of advanced computers for such things as industrial design and management is progressing faster in the civilian sector than in the defense sector. As a result, the design and production of electronic devices and systems cost more in the defense sector than in the civilian, reflecting the need to produce specialized circuits in the thousands instead of the millions, to use specialized production facilities, and to pay the overhead resulting from smaller production runs that require special attention in manufacture and quality control. Although the declining importance of the defense market has not prevented the military from advancing its electronic systems capabilities, it has considerably raised the price of doing so. Similar cost penalties exist in other areas, such as advanced materials.

Some of the interactions between the economics and politics of the weapon system acquisition process must also be recognized. To control the high cost of defense, Congress desires (correctly, in principle) that weapon systems be acquired within the competitive industrial system. On the other hand, costs induced by the very process of competition can negate the anticipated savings. These costs are created by the demand for duplication of major system prototypes, such as the two separate models of the lightweight fighters destined to become the F-16, and later, the F-18. Competition in the procurement process also entails considerable duplication of startup investments, which can only be recovered if enough quantities of weapons are bought so that the savings resulting from lower unit prices offset the added costs of competition. Not all system acquisitions are large enough to effect such compensation, however, which means that competitive acquisitions can become more expensive than their advocates desire.

Congress has also mandated that as a condition of acceptability, all systems must be tested and demonstrated to work in an operational, or real-world, environment. Although such a requirement cannot be argued with, it adds to the total cost of a system and the time to field it. Moreover, the trend toward greater use of warranties for military equipment, also mandated by Congress as a means of controlling costs, can increase costs as well as lower them, because companies compensate for their inability to control the conditions of maintenance and repair by adding warranty charges into their equipment prices.

Finally, the logistics requirements to support modern equipment, with its high proportion of electronic components, are changing rapidly. Defense systems based on large-scale integrated circuitry require built-in diagnostic and test equipment simply to ascertain the cause of a failure. Beyond that, these systems cannot be repaired, in the sense of fixing components or replacing subordinate parts like vacuum tubes, as was done two decades or so ago. Rather, entire assemblies must be discarded and replaced. As a result, the flow of spare assemblies from factory to user is in some cases replacing the use of large inventories of spare parts in intermediate depots. In addition, the entire logistics system must be computer controlled. While these changes may make maintenance easier overall, they can also increase its costs. (Electronic equipment in the solid-state age is, however, generally becoming far more reliable than it used to be in the vacuum-tube age.) At this stage, the methods and machinery of the logistics system have yet to adapt to the new requirements posed by advanced technology.

These are only some of the factors that influence cost, in addition to the basic expense of developing and buying very advanced and often experimental technology in military systems. Despite all the efforts to control costs, there is a level below which they cannot be pressed if the military systems are to be able to meet the opposition. In this environment, institutional constraints on how the military budgets are spent can play a dominant role in determining the shape and evolution of the armed forces.

The patterns of development of military technology are affected by the industrial and the research and development communities that have grown to help acquire that technology. Whatever the extent to which technological advance in the military is "threat driven," it is also influenced by the need to maintain a stable manufacturing and R&D capability in the industrial sector. In practice, this means that while one generation of military equipment is being acquired and distributed through the armed forces, the defense establishment starts planning and working on the next generation.

To say this is not to be pejorative about the "military-industrial complex." The symbiotic relationship between the creators of military capability and the users of that capability must continue if our military forces are to remain ahead. On the other hand, several decades of such a relationship have created industrial patterns in the United States that are very difficult to change. For example, about twice as many technical people—engineers and scientists—are employed in the aircraft industry as are employed in the electronics and weapons industries. If enough effort were shifted from aircraft manufacture to the manufacture of weapons and electronics to change the weapon/platform balance, major changes in the defense industry would be necessary. To reverse the employment ratio, for example, would entail closing some aircraft factories and opening new missile and electronics plants, with attendant retraining of production workers and shifts of technical skills in the engineering staffs of the companies. Such changes cannot be undertaken lightly: they are difficult to effect, difficult to reverse once implemented, and entail large material and human costs.

Such changes must not be undertaken lightly: they are difficult to effect, difficult to reverse once implemented, and entail large material and human costs.

Such factors lead to a certain stability in our military services. They have developed career patterns for which there are strong constituencies. This tends to make for forces that, while they do not necessarily support the status quo, channel technological change in particular directions—namely, a preference for the improvement and renewal of the platforms that support the institutional basis of the armed forces, rather than for large-scale acquisition of new kinds of weaponry and new kinds of electronic systems to make that weaponry as effective as possible. This stability is reflected in the funding patterns shown in Figures 1, 2, and 3.[2]

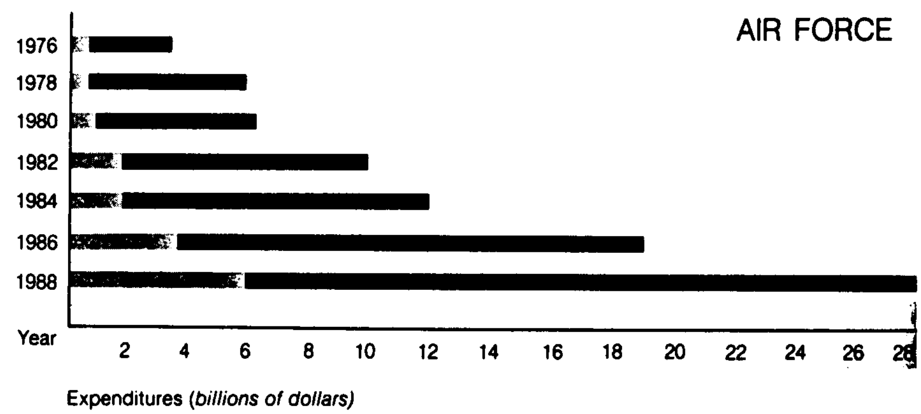
Clearly, international politics, the national and international economic system, and society's institutional patterns exert different pressures on the potential rate and direction of technological change in the armed forces. If the new capabilities in the offing were advanced at the greatest possible rate, the roles of platforms would become secondary. They would have the tasks of carrying and launching the machinery that really does the military job. However, as Figures 1–3 show, most of our military budgets and most of our armed forces' attentions have been concentrated on developing expensive new platforms. The new platforms with their subsystems will offer some of the new capability to know where the enemy is, to acquire targets, and to shoot at those targets. But they will do so at great expense if they do not use the new weaponry to the fullest.

We have focused on resistance to a change that results from costs and institutional constraints in the armed forces and society. Yet there is also ample technical reason to be conservative about change. The new systems do entail risks. They are subject to countermeasures, and under some conditions they will not work as well as the old, familiar kinds of systems. The new systems rely more on technology to do things that people traditionally have done. Therefore, these systems may be more subject to total failure because they lack human adaptability and the ability to improvise. The new systems represent elegance, not mass—and in war, elegance is often very difficult to achieve or to maintain.

V

Three views have developed about the best way to manage technological change in the armed forces. The first says we should buy the most advanced platforms that we can, those best able to withstand the "threat"—that is, best able to deal with similar systems of potential adversaries. And, according to

FIGURE 1:
ALLOCATION OF EXPENDITURES TO GUIDED WEAPONS AND PLATFORMS



Key:
Guided Weapons *(missiles)*
Platforms *(aircraft)*

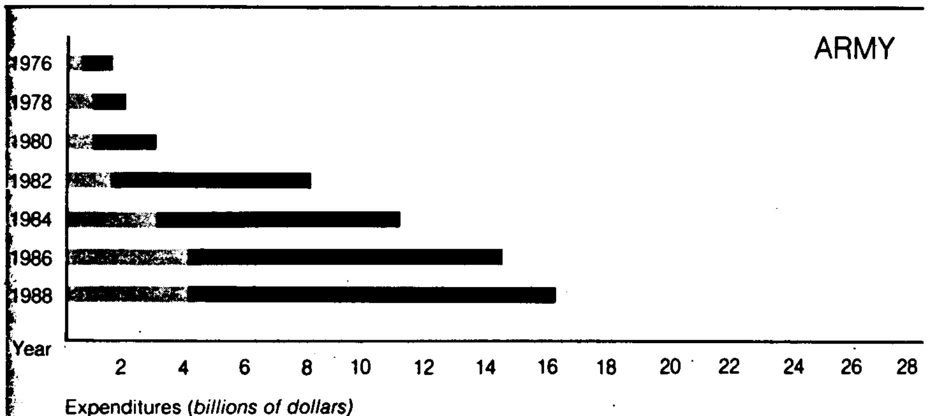
Source: Institute for Defense Analyses, from Department of Defense data. Total obligational authority, 1984-88 projected.

that view, we should augment the advanced platforms with very sophisticated weapons and supporting systems, to the extent that defense budget levels permit and that military tasks demand. This view is espoused by the military services and is essentially the approach followed today.

The second view argues that since the new guided weapons will be highly effective, platforms need never be improved at all. Thus, by not buying as many platforms and not spending precious research and development money on improving their capability (and thereby running up their costs), it will be possible to reduce both forces and defense budgets quite drastically. In effect, this view says that the new guided weaponry and its auxiliaries will enable us to fight and win wars "on the cheap." This view was articulated in perhaps its most extreme form in an article by Paul F. Walker in *Scientific American* in August 1981.[3]

The third view, advanced by the "defense reform" community, essentially says that military technology has become too costly, that the new equipment is too difficult to use and to maintain, and that it will not work when the armed forces do use it. These reform views can be found in James Fallows' *National Defense*, and are subscribed to by Sen. Gary Hart (D-Colo.) and many others.[4] They argue that technology for its own sake has been allowed to dominate weapon system design. In our search for quality, they say, we have run up the costs of weapon systems and have thus lost the ability to acquire them in sufficient quantity—and we have failed to achieve the desired quality as well. By backing away from the most advanced technology, they say, we can make weapons simpler, cheaper, and easier to use and thereby make our general purpose forces larger and sturdier.

None of the three proposals provides a workable solution to the problems the military services face in adapting to the advances in military technology. The first—continued concentration on improving platforms, while adding



Source: Institute for Defense Analyses, from Department of Defense data. Total obligational authority, 1984-88 projected.

FIGURE 2: ALLOCATION OF EXPENDITURES TO GUIDED WEAPONS AND PLATFORMS

Key:
Guided Weapons *(missiles)*
Platforms*

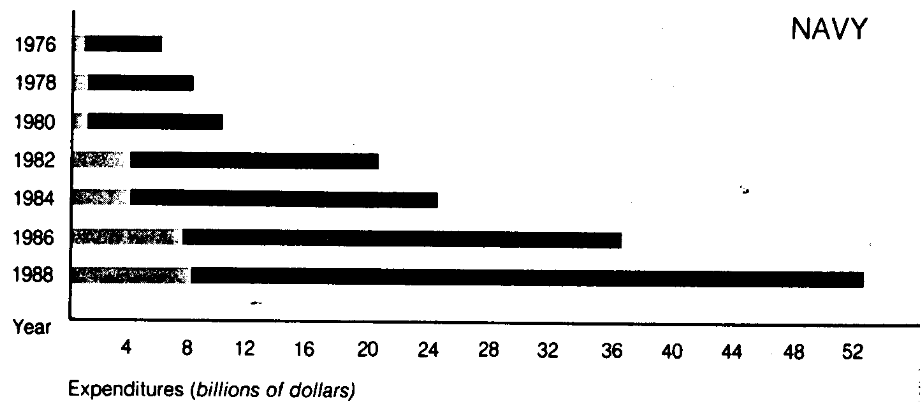
* *includes aircraft, armored vehicles, and some associated conventional weapons.*

new weapon and support systems when budgets allow—is very costly. Within "affordable" defense budgets, the forces that can be acquired therefore continue to shrink. By contrast, the Soviet Union, which can exact much greater privation from its population than is possible in the open societies of the West, can maintain the size of its armed forces. Thus, although our military systems may be individually far superior to those of the Soviet Union, the greater weight of force that the Soviets can bring to bear may enable that nation to overcome the West's most advanced technology.

In addition, our overconcentration on platforms, at the expense of modern weaponry, has created a paradoxical situation: we spend enormous sums and demonstrate remarkable abilities to move forces rapidly over very long distances, without having effective combat capability at the end of the line. Our combat capability suffers both because our forces are shrinking and because their weapon and target acquisition systems have not been improved to the greatest degree possible. For example, despite occasional illustrations of extremely accurate bombing (such as the attack on the Iraqi nuclear reactor by the Israeli air force) unguided bombs are, in the main, far less accurate and therefore less effective than guided weapons. Similar performance differences characterize artillery and other weapons. Thus, to be as effective as guided weapons, unguided weapons must be used in more sustained and repetitive attacks. If forces are reduced by budget constraints, as happens when we concentrate on platforms, they are less capable of delivering such attacks, and they are excessively penalized by combat losses.

The problem with the second approach—total concentration on guided weapons—is that the anticipated savings will simply not be there. Military forces equipped with guided weapons will be just as costly as forces equipped with improved platforms, once the costs of all the supporting systems needed to deploy the guided weapons on the battlefield and to overcome the effects of

FIGURE 3: ALLOCATION OF EXPENDITURES TO GUIDED WEAPONS AND PLATFORMS



Source: Institute for Defense Analyses, from Department of Defense data. Total obligational authority, 1984-88 projected.

Key:
Guided Weapons *(missiles)*
Platforms *(ships and aircraft)*

countermeasures and the "dirty" conditions of combat are considered. The allocation of funds will be different, but the level of funds required will not. For example, advocates of the second approach often say that a guided missile costing a few thousand dollars can destroy a tank costing $1 million or $2 million. The comparison is spurious. By the time a guided anti-tank weapon is aimed and fired at its target, it costs just about as much as the target, given the vehicle that must carry the guided missile and gunner (in an environment protected from small-arms and artillery fire) and the target acquisition and command and control systems that must integrate the missile into the anti-armor force. This is true in all areas when guided weaponry and its auxiliary systems are substituted for very advanced platforms.

Nor will the third approach (slowing down our participation in the military technological revolution) work. First, the resulting forces would be less capable than they could and must be; and second, there would be no savings on manpower, which is the most expensive single component of the armed forces. In addition, our society clearly wishes to limit the amount of manpower in the armed forces. This nation has not been willing to maintain forces as large as those of the Soviet Union. In fact, in the 1960s and early 1970s, all NATO forces combined had only slightly more than half as many personnel per thousand of population in the armed forces as the Soviet Union, and that fraction has been declining since.[5] Thus, the hope that we could exchange very high-quality (but possibly unreliable) systems for a larger quantity of simpler and more reliable systems—the quality/quantity issue that is at the heart of the defense reform debate—is misleading. It would not work as advertised in the United States.

It is also well to note, however, some of the criticisms of the weapons acquisition process. For example, the accusation that systems tend to be gold plated by excessive performance requirements, which add unnecessarily to cost, complexity, and acquisition time, cannot be entirely dismissed. Nor can charges that waste, fraud, and abuse in the acquisition process greatly reduce the efficiency and effectiveness of the armed forces in particular cases. We must work diligently to reduce such mismanagement to the greatest extent possible. However, we should also remember that such mismanagement is characteristic of any human endeavor, not just that of the defense sector; nor is the defense sector more subject to it than others. Moreover, these problems would plague the acquisition and operation of the armed forces under any of the three philosophies described above.

VI

Clearly, our defense structure and our military forces will have to change if they are to come to terms with the new conditions being imposed on them both by the advances in technology and by the pressures for change in the outside world. In the remainder of this article, I will suggest some steps that might be taken to ensure that we have the most effective military capability in the coming decades.

First, to reduce their vulnerability to enemy counteraction, the technical characteristics of the military forces must change. They must begin to rely on a combination of long-standoff missilery and other technological means, such as far more extensive application of electronic warfare in all its aspects, to prevent their platforms from being destroyed. As military forces evolve in this direction, many of the advanced platforms now being planned may prove to be less necessary and desirable than is currently believed, because the main combat load will have been shifted from the platforms to the standoff guided weapons and related systems. And as the military forces increase their use of electronic warfare, their equipment, tactics, doctrines, and means of weapon delivery will have to change. Specifically, more explicit and sustained attention will have to be devoted to the integrated acquisition and use of the electronic warfare systems and guided weapons. In this situation, the new systems will compete with the platforms for resources, and difficult choices will have to be made. Moreover, the need for improved effectiveness at the "point," where a force performs its mission, makes essential the extensive adoption of guided weaponry and its major associated systems for command and control and for target acquisition.

Where can the resources be found to implement such changes? Typically, platforms—that is, ships, aircraft, and to some extent major ground-force systems like tanks and fighting vehicles—have total acquisition costs that are greater by factors of five to seven than the typical costs of major missile systems and their auxiliary systems.[6] For example, the total acquisition of the Infrared Maverick air-launched anti-tank missile, considered an expensive system, will cost about $5 billion for several tens of thousands of missiles. The F/A-18 Navy aircraft acquisition will cost about $32 billion. Obviously, if acquisition of one or more platforms were stretched out or even forgone, resources would be freed to acquire more of the systems that are at the cutting edge of military technology.

Second, we must change our procedures for acquiring and supporting systems, thereby reducing the costs of these cutting-edge systems. For example, we could plan ahead for total acquisitions of tens or hundreds of thousands of missiles, once they have been shown to work effectively, instead of acquiring a few hundred year by year for an indefinite period. Given our existing acquisition procedures for weapon systems (and this applies to platforms as well), no industrial firm can build the large-scale manufacturing facilities and tooling appropriate to the size of the ultimate purchase, because they have no assurance that such investments will pay off. In addition, because the incentives for cost reduction inherent in mass production are usually absent, the incentive for efficient designs does not exist either. Inefficient technical designs that in turn induce manufacturing inefficiencies also carry costs. As a result of such factors, when binocular-quality optics and home-computer-quality circuits are used in a guided weapon, the weapon parts cost an order of magnitude more than their counterparts in civilian assemblies.

If acquisition of one or more platforms were stretched out or even forgone, resources would be freed to acquire more of the systems on the cutting edge of military technology.

Finally, we can reduce costs by changing the logistics system. This would include ensuring that adequate spare parts are provided and that maintenance methods are modernized. We could adapt some civilian practices to the support of military technology. For example, civilian firms could perform important maintenance in all areas except the immediate battlefield, thereby reducing the military's reliance on large, vulnerable depots for maintenance operations. While this approach would entail certain risks, such as strikes that might interfere with the provision of spare parts, these could probably be mitigated by various economic and legal measures.

Third, the services should undertake much more joint and cooperative system acquisition and utilization. The services cannot continue to go their separate ways, with overlapping system requirements and developments or with incompatible "interfaces" that can only be remedied in the field at great expense (such as command and control systems that cannot exchange data). Nor can they continue with redundant major system acquisitions justified to meet special requirements that each service claims are unique to its own operations and missions. The resources for these luxuries of service independence simply do not exist today. Furthermore, in the purely military sense we cannot afford the loose connections among the services that these practices encourage, because economy of force requires integration of the systems of warfare at all levels in the field.

Fourth, we must solve the problems that arise from competition with our allies in arms sales. As already mentioned, this competition encourages sales of advanced weaponry to the unstable Third World, making it—and therefore the entire world—a more dangerous place to live. The conflicts that have erupted into open warfare dozens of times since World War II have all occurred in the Third World, where local rivalries and clashes of major powers over resources and political dominance make armed conflict a high risk. The industrialized world must recognize that it is making these conflicts more difficult and dangerous for itself by arming the quarreling factions.

Finally, we must reexamine how we use manpower and womanpower in the armed forces. The arguments about women and the draft, for example, often raise the question of whether women should engage in combat. However, whether women are involved in depot maintenance; in operating air defense systems around cities, airfields, or major bases; or in ferrying airplanes into a theater of war as they did in World War II, modern warfare is such that they will be exposed to combat. The wider use of electronics means that combat systems will be distributed in rear as well as forward areas. It also means that physical strength will become important mainly at the point where opposing troops are in contact—and such involvement may be a far smaller part of a total military conflict in the future than in the past.

The pool of personnel able to handle sophisticated equipment must be enlarged—and personnel and their training are expensive. The other alternative is to slow the pace at which sophisticated equipment is adopted so that less capable personnel can handle the systems. In the long run, this will lead to less capable armed forces.

Attempting to slow the pace of technological advance in our armed forces will leave us with military capability inferior to that of our opponents, and will leave us unable to lead our allies in our collective defense. Clearly, technological change in the armed forces will and must come; the critical question is how well we manage that change. If we fail to take full advantage of the new capabilities, if we fail to exploit our genuine lead in electronics, we will sacrifice an opportunity for an enduring military superiority. ■

NOTES:

1. Discussed at length in chapter 8 of my book, *Military Power and the Advance of Technology: General Purpose Military Forces for the 1980s and Beyond* (Boulder, Colo.: Westview Press, 1983).
2. Adapted from *Military Power and the Advance of Technology*, chapter 11.
3. Paul F. Walker, "Precision-Guided Weapons," *Scientific American* Vol. 245, No. 2 (August 1981).
4. James Fallows, *National Defense* (New York, N.Y.: Random House, 1981).
5. Data from the Arms Control and Disarmament Agency, *World Military Expenditures and Arms Transfers* (annual publication series).
6. See, for example, table T-6 of my article "The Future of Tactical Air Power in Land Warfare," *Astronautics and Aeronautics* Vol. 18, No. 7/8 (July/August 1980).

SMART WEAPONS: BUT WHEN?

Richard L. Garwin

PROLOGUE: *The application of modern technology to warfare may be easier than Seymour Deitchman suggests, writes Richard L. Garwin. He illustrates with three examples how certain existing technologies might be introduced: using guided weapons to provide theater-wide accurate artillery fire, using advanced surveillance systems to mount an effective theater air defense, and using modern electronics to control the arming of hand-held anti-tank weapons so that they can be safely distributed among militia forces.*

The key to the introduction of new weapons systems in the face of institutional and other barriers, Garwin argues, is to field a "vertical slice" of capability so that all elements of the system can be evaluated as to performance and cost and can be demonstrated in large field trials.

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Seymour Deitchman paints a dismal picture of our choices in applying available technology to improve the capabilities of our military forces. (p. 83) Potential vulnerabilities, institutional rigidity, and the prospect that a massive shift in employment would follow a rational reallocation of funds to platforms, weapons, sensors, and manpower are all cited as barriers to the application of technology to conventional warfare.

These impediments exist, and the internal incentives are currently insufficient to overcome them. Nevertheless, if we are concerned with our military capability—or with the cost of achieving it—technology can provide greater effectiveness for our defense dollar.

In this article I describe three applications (out of many) of existing technology that could contribute significantly to the effectiveness of our military forces. After sketching these three examples of opportunities to apply technology to particular combat missions, I suggest how we might introduce these new capabilities into our armed forces.

As Deitchman indicates, military procurement is now a small part of the total market for advanced microelectronics. The military have much to gain by adopting off-the-shelf civilian technology, as was demonstrated in the late 1960s when an enterprising Navy commander in Vietnam installed Sony TV sets in his F-4 aircraft to provide more effective and reliable video displays.

Many systems similar to those discussed below were proposed by the Military Aircraft Panel of the President's Science Advisory Committee during the 1960s. Elements of these systems were introduced during the Vietnam War in connection with efforts to halt North Vietnamese infiltration into Laos, and more recently by Israeli forces in Lebanon (where, for example, the Israelis have used small radio-controlled drone aircraft equipped with television for battlefield surveillance).

II

The first example is *Theater-Range, Accurate Artillery*. The 5-to-25-kilometer (km) range of modern artillery imposes a significant logistics and manpower burden on armed forces. Guns, ammunition, and crews must be deployed within range of their targets and within range of the line separating friendly and enemy forces. But much artillery is not productively used because the enemy is advancing elsewhere and there are thus no rewarding targets. Artillery of the 300-to-500-km range (at the same price) would, of course, be preferable, since the fire could be massed from hundreds of kilometers away onto an enemy salient. Guided weapons allow such massing of fire without any loss of accuracy induced by the vastly increased range, and the cost of a guided artillery shell depends little upon its range.

To use guided weapons with theater range (300 to 500 km) requires a surveillance system capable of finding rewarding targets. It is possible to use the same ground- or air-based forward observers that direct existing short-range artillery fire. The modifications required to link these observers to a theater-wide artillery system are more organizational than technological since the existing communications network could easily be linked to a theater fire-control headquarters. Thus, available resources could be used more effectively than by assigning individual artillery pieces to individual companies or battalions deployed on a front line hundreds of kilometers long.

Substantial elements of a real-time, theater surveillance system covering a region some 1,000 km across already exist. These elements would have to be supplemented by a robust theater communications system. As indicated, surveillance can be carried out in part by forward observers on the ground and in part by small drone aircraft, equipped with television cameras or other sensors, that are able to obtain precise knowledge of the target position. Once a target is identified and located, attacking weapons can be guided to the target by using a navigation grid common to the sensors and to the weapon.

The necessary communication system can be provided in large part by phased-array antennas carried aloft by helicopters at an altitude of some 5 km, which scan like a radar to provide encrypted commands to the surveillance drones. This line-of-sight communications system would be capable of narrow-beam, high-power (time-shared) transmission for receiving television pictures rapidly from a drone that requested communications service. The helicopters provide agile platforms for phased-array antennas that make it difficult for an opponent to jam communications relayed from surveillance aircraft to ground units.

Helicopters provide agile platforms for phased array antennas that make it difficult to jam communications relayed from surveillance aircraft to ground units.

Surveillance drones must be inexpensive (perhaps a few thousand dollars apiece), preferably costing less than the systems required to shoot them down. Flooding the battlefield with uninstrumented decoy drones would help improve the cost-exchange ratio by overloading enemy defenses. It will often be necessary to operate the drones at low altitude to remain below cloud cover, and battlefield dust and smoke will degrade their capability.

The artillery in this theater-range system would consist not of traditional tubes but of conventionally armed ballistic (or cruise) missiles, either ground-launched or ship-launched. For a range of some 500 km, ballistic missiles can be cheap and can have a short response time, an important factor when attacking mobile targets. The ground-launched missiles would be stored in individual concrete silos at airfields and would emerge from their silos under radio control. Missiles could also be launched from military cargo ships offshore, with the communications relay system providing flight and target information to the missiles during their early boost phase.

Using a typical solid rocket fuel for tactical missiles, a 100-kilogram (kg) payload requires an initial mass of 270 kg to propel the warhead 500 km. The payload could include a guidance and maneuvering system weighing 20 kg and an explosive warhead of 80 kg. In fact, a missile of any size could propel 0.37 of its initial mass to a range of 500 km in approximately 315 seconds with a single-stage rocket containing a propellant with an exhaust velocity of 2.24 km per second. The missile, provided with rough azimuth and range, would rise vertically from its silo, pitch over, terminate thrust, and separate the reentry vehicle that would then follow a ballistic path above the atmosphere to reentry. Without a guidance and maneuvering system, the warhead on atmospheric reentry would not land close enough to the intended target.

A satellite Global Positioning System (GPS) receiver in each missile would relay data to the elevated antenna, which would provide computation services for all missiles in flight at any one time. As the missile neared the terminal area and small maneuvering fins were deployed, greater communications and computation services would be allocated by the theater communications system to command the missile to the predetermined location of its intended target, with an error of 15 meters or less. Similar GPS receivers on the drone surveillance systems, together with modest inertial instruments supporting the television camera and laser range finder, would provide accurate information as to locations of targets on the ground.

Missiles could deliver munitions of either 100 kg or 1,000 kg size. If the system were widely deployed, a broader range of payloads would be more economical. Several types of warheads would be stocked—bomblets for attacking troops, high-explosives for tanks, and strike-mines for emplacement in the path of an advancing column. A 1,000-kg, high-explosive, penetrating warhead would be used to attack bridges and structures.

Munitions would be delivered to the vicinity of moving targets, with knowledge of target positions continuously updated by surveillance drones. By remotely controlled maneuvers in the terminal area, the munitions could then be made to strike the moving target. Surveillance drones could also designate targets with lasers detected by a homing system in the missile warhead like that which has been available since the late 1960s in the laser-guided bomb.

III

The second example is *Theater Air Defense*. In the U.S. armed forces, defense against enemy aircraft is performed primarily by Air Force interceptor aircraft armed with homing missiles and guns, or by surface-to-air missiles (SAMs) directed by ground radars and under the control of the Army. In general, the interceptors or SAMs are called up by the overall theater air-defense system, which relies on ground-based search radars and advanced aircraft such as the Airborne Warning and Control System (AWACS) that can track aircraft-size targets moving over the ground even when the AWACS is flying at jet speeds.

The ground-based radars and AWACS provide early warning of enemy aircraft adequate for directing missile-site radars or fighter interceptor radars to lock onto the individual targets. Advanced missile-site radars such as PATRIOT have a track-while-scan capability that permits them to track dozens of aircraft and missiles while continuing to scan for additional enemy aircraft. The technological virtuosity embodied in the AWACS results in an aircraft costing some $100 million—a prime target for enemy attack during wartime. Furthermore, the interceptor aircraft cost from $15 million to $30 million each, and carry missiles costing $100,000 to $1 million apiece with ranges of a few miles to a hundred miles or more.

One major problem to be overcome in mounting an effective air defense is to distinguish between friend and foe. The presence in the defended air space of friendly fighter and interceptor aircraft greatly inhibits the utility of long-range missiles launched either from aircraft or from the ground. An effective Identification Friend or Foe system (IFF) is a necessity, but such a system has not yet been provided even for North Atlantic Treaty Organization

(NATO) forces in Europe.

Because our high-performance aircraft (including air-defense aircraft) are based on airfields, our air defense is dependent on the survival of those airfields. Thus, the struggle for air superiority, contrary to popular conception, is largely a question of which side can destroy the airfields of the other side first.

The task of theater air defense is best performed by long-range SAMs that are responsive to an air-defense information system fed with information from ground-based and elevated radars. The elevated radars would be phased-array radars held aloft at altitudes of 5 to 15 km by helicopters or balloons and capable of separating the radar signals of even small, slow aircraft from ground clutter by Doppler filtering. After identification of an enemy aircraft, a SAM would be launched by radio command and boosted to a speed of some 2.2 km per second (Mach 7) on a ballistic trajectory to reach a target 500 km away in 5 minutes. As it approached the predicted position of the target, the SAM warhead would deploy small aerodynamic surfaces required for high-performance maneuvering within the atmosphere, and would home on the enemy aircraft.

The struggle for air superiority, contrary to popular conception, is largely a question of which side can destroy the airfields of the other side first.

The primary homing method would employ the modern analog of the so-called semi-active, continuous-wave homing scheme, whereby a beam of microwave energy would be projected from the airborne radar in the direction of the enemy aircraft. That portion of microwave energy reflected from the aircraft and received by the missile warhead would serve as a beacon; a set of microwave detectors in the missile would provide steering signals to the warhead guidance system.

The rotating radar antenna of the AWACS and its signal-processing electronics enable it to see moving targets against the ground. These electronics filter out the very large signals returned from the ground (so-called ground clutter) from the signals returned from moving objects. Thus, the AWACS can see aircraft without interference in most directions if the aircraft are moving with sufficient speed over the ground toward or away from the AWACS. The speed that makes a jet aircraft so productive for transporting people and cargo is thus a disadvantage in the radar surveillance role. A stationary elevated antenna is far simpler and less costly for the task of distinguishing moving targets from ground clutter.

In 1970 the Air Force conducted trials of a transportable Army radar suspended from a helicopter and achieved very good moving-target detection. No data processing was done in the helicopter, the raw radar signals being transmitted by data link to the ground and incorporated into the ground-air information net as if they had originated at a ground radar station. It may be that this very successful demonstration was not followed by deployment of a perfected system because the Air Force was committed to an autonomous radar aircraft providing both detection and command and control.

Ordinary helicopters can fly at an altitude of about 5 km, half that of jet aircraft, thereby limiting their radar horizon to about 250 km, some 70 percent of that for the AWACS. Helicopters designed and equipped for high-altitude hover would remove this performance penalty. Balloons have also been used to support radars for more than a decade in Florida (providing surveillance of Cuba) and in the Middle East, operating easily at a 15-km altitude with a radar horizon of 430 km. However, multiple, shorter-range, and cheaper elevated radars may offer less inviting targets for enemy attack and therefore may be more cost effective than a single, sophisticated antenna operating at an altitude of 15 km.

The 1970 Air Force trials were conducted with a continuously rotating radar antenna, the type presently used by the AWACS. While it is not yet possible to fit the AWACS with an electronically scanned, phased-array antenna, such an antenna could be used on a hovering helicopter or balloon. It would then give the helicopter the ability to track enemy aircraft continuously and accurately (as well as to provide the IFF function) and thus to serve as a highly capable, difficult-to-jam, elevated, command and receiving relay antenna for missiles launched at enemy aircraft. The anti-jam capability comes from the unpredictable time at which the antenna is commanded to "look" at the missile, the narrow beamwidth, the high available power, and the wide bandwidth for such a direct line-of-sight link.

Effective defense cannot be mounted without an overall Air Defense Information System (ADIS). This system currently consists of the radars, the communication links, and the personnel, computers, and procedures for assigning interceptors to targets. By adding to these elements the radar information from the elevated antenna and the availability of a ballistic-flight, aerodynamically maneuvered, semi-active SAM of 500-km range, it should be possible to achieve theater air defense at lower cost than that obtained by dispersing short-range SAMs throughout the theater. This system also reduces the cost and vulnerabilities associated with manned interceptor aircraft and in large part removes these aircraft from friendly airspace to allow freer use of SAMs.

As with theater-range artillery, it is necessary, of course, to provide a robust communication and control system. Thus, there must be backup radars and helicopters (or balloons); multiple control centers, including replicated underground shelters and vans; properly placed communication antennas at some distance from the centers so as to avoid the possibility of enemy weapons destroying the centers by homing on the communication signal; and the like. A system on which the effectiveness of NATO forces depends in wartime cannot be configured as a chain of communications links but must have the characteristics of a network, even though it may be preferable to have only a single link operating at one time.

The elevated line-of-sight antenna called for in our discussion of theater-range artillery is provided by the electronically steered antenna of the air-defense system just described, so that air defense and artillery can share the same communications system. The military is traditionally fearful that joint-use systems (whether used for different functions in the same service or, even worse, shared by the Air Force and Army) will be unavailable at a critical time. This problem can be resolved by providing the redundancy and overcapacity that has long characterized the U.S. commercial telephone system.

Of course, this is just a sketch of the concept. The modern analog of semi-active, continuous-wave homing is far more robust than the traditional system, since the wide-bandwidth coded pulses from the electronically steered radar can provide much anti-jam margin against attempts to deceive the warhead guidance system. The warhead could have the usual home-on-jam capability, and the overall system could be upgraded to meet more sophisticated threats.

IV

The third example is *Distribution of Controllable Anti-Tank Weapons.* There are far more people on the modern battlefield than tanks, and in the end NATO's defense of Western Europe could rely heavily on militia and reservists. Some of these citizen soldiers will be armed with modern versions of the hand-held World War II bazooka, which, like the post-war Soviet RPG-7, will do a good job of killing a tank if it scores a hit from an appropriate direction. One has the choice of firing an unguided weapon from close range or of increasing the complexity and cost of the weapon by providing it with a sophisticated guidance system that will enable it to be fired from longer range.

The vulnerability of tank-fighting infantry can be reduced by a system that uses an optical or electronics periscope to allow firing from cover.

A primary problem in the use of hand-held anti-tank weapons is that the soldier launching the weapon is vulnerable to hostile fire from the targeted tank during the flight of the (subsonic) rocket and is exposed to suppressive artillery fire covering the tank attack. Anti-personnel shrapnel is harmless to tanks but can be effective against foot soldiers lying in wait for opportunities to launch anti-tank rockets. The vulnerability of tank-fighting infantry can be reduced by a system that uses an optical or electronic periscope to allow firing from cover and that allows the rocket weapon to be positioned some tens of meters away from the person launching the weapon. The introduction of such improved weapons into our defensive forces should receive high priority.

Unfortunately, such anti-tank weapons would be highly potent in insurrections or in criminal activities. For this reason they are unlikely to be widely distributed among militia. But modern civilian electronics now make it feasible to extend to these hand-held anti-tank weapons the permissive-action link (PAL) concept introduced by the United States in the early 1960s to prevent the unauthorized use of U.S. strategic and theater nuclear weapons, and thus to allow a more effective deployment of nuclear weapons. The original PAL was an electromechanical combination lock that ensured the disablement of the firing circuit to the nuclear weapon unless the proper combination had been entered into the weapon itself. The electronics are so closely integrated with the explosive warhead and the firing system that a proper launch or warhead explosion cannot be obtained without the code.

It is now possible to have the flexibility of releasing a large subset of weapons at once by means of a master key combination or by releasing weapons separately with individual keys. Weapons can also be released for a short time only, after which the temporary key would no longer work and the weapon would become dormant. If such weapons fell into unauthorized hands, their explosives could be extracted; but there are easier ways to obtain such supplies. If necessary, the PAL concept could also be extended to discourage removal of explosive charges.

V

These are only three examples of weapons systems that fit many of the requirements—reduced vulnerability, cooperative operations, and considerations of cost and staffing—set forth by Deitchman for the efficient use of modern technology. Elements of each system could be procured by the tens or even hundreds of thousands. They require no exotic materials or extensive training of personnel. Yet they have not been deployed.

None of these concepts, of course, fits the existing military structure, and each would compete with some traditional way of accomplishing a defense mission. How, then, could our military establishment decide to change to a new and untried system? The answer is, it could not.

The key to the successful introduction of new systems is not to insist on agreement for a drastic overall change. It is preferable to develop and field a "vertical slice" of capability, containing all elements of the new system. If it were decided to introduce only theater-range, ground-to-ground missiles to supplement traditional artillery, they would have to be integrated into the existing fire-support system. Existing communications are inadequate, and the costs would be enormous. On the other hand, by developing and demonstrating as a unit the elements required for the entire theater-range missile system, the number of troublesome external interfaces can be held to a minimum—thus the term "vertical slice."

The technology for each new weapons system could (and should) be developed, perfected, and tested by a single prime contractor—either a commercial firm or one of the major national laboratories. Using functional prototype hardware, the new capability could be evaluated for performance and potential cost. It could then be purchased and introduced to serve a battalion or division and demonstrated in large field trials.

It is erroneous to assume that sophisticated military technology is invariably expensive and unreliable and that it imposes major new requirements for staffing and training. This misperception results from deploying technology that has not been proved in the field and has not been tested by several generations of prototype use. If a newly proposed and tested system is not greatly superior to existing systems, it should not advance beyond the prototype stage into production and deployment.

With adequate attention to requirements for thorough development, testing, and evaluation—and with a resolve to reject inadequate systems so that perhaps only one-third of those tested are ultimately deployed—there is every reason to expect that existing and new technology can be applied to improve the capabilities of our conventional military forces and to lower their cost. ■

A DOUBTFUL REVOLUTION

William S. Lind

PROLOGUE: *In his comment William S. Lind questions the validity of Seymour Deitchman's underlying premise: that the modern world is in the grip of a general technological revolution and that this revolution will have a profound impact on conventional warfare. Lind doubts the battlefield utility of many new-technology weapons, noting the questionable effectiveness of guided anti-tank missiles under combat conditions.*

The military reformers, he argues, do not refuse to make use of advanced technology but rather are insisting that it be applied in militarily appropriate ways. Technology should be used to meet actual combat needs, he writes, and not to fulfill the ambitious dreams of technologists.

William S. Lind received his A.B. from Dartmouth College in 1969 and his M.A. from Princeton University in 1971. He has worked as a legislative aide on defense matters since 1973, first for Senator Robert Taft, Jr. (R-Ohio), and since 1977 for Senator Gary Hart (D-Colo.). Lind is the author of the Maneuver Warfare Handbook *(to be published early this year), and is currently coauthoring a book with Senator Hart on military reform.*

Seymour Deitchman's article (p. 83) reflects two assumptions: first, that we are in the midst of a general technological revolution, and second, that this technological revolution will have enormous effects on warfare. Both of these assumptions are open to question.

Let me comment first on the second assumption. Deitchman's assertion that we are in the midst of a period of revolutionary change in military technology and that this will have a profound impact on conventional warfare is unsupported by observable military experience.

Deitchman argues, for example, that "We are . . . gaining the ability to fire guided weapons at the enemy that hit targets with far higher probability than the unguided weapons that were used in the past." This statement is wrong on several counts.

Consider one highly touted family of guided weapons, the guided anti-tank missiles such as TOW, Dragon, Sagger, Milan, and HOT. In theory, these weapons have very high probabilities of kill—much higher than those of classic anti-tank cannon. In controlled peacetime tests on the proving ground, they have sometimes demonstrated these high probabilities of kill, even though the most recent peacetime firings have produced fewer than one hit out of each three shots.

Results in combat, however, are very different. In the 1973 Mideast War, the Arabs fired more than 80 Saggers for each Israeli tank killed by one of these Soviet-built missiles. Moreover, a simulation conducted by the U.S. Army at Fort Leavenworth indicated that for each tank killed by a Dragon (a U.S. weapon), the tanks would kill seven Dragon crews. Why? There are few long-range shots in combat because of problems presented by terrain, weather, smoke, dust, and enemy tactics. In simulations based on European and Israeli terrain conditions, half the engagements were at distances of less than 500 meters. Most of the time, the missile gunner's firing position is within range of some hostile tank's machine guns. Unlike an anti-tank cannon shell, the missile has a relatively long flight time—long enough for the tanks to lay down heavy machine-gun fire on the firing position while the missile is still in flight. Even if the missile gunner is not killed, his aim is likely to be thrown off.

In other cases some of the new-technology weapons may be more accurate—laser-guided bombs, for example, may be more accurate than regular iron bombs. The greater accuracy, however, may be meaningless. If an attempt is made to use these weapons against moving targets on or near the battlefield, the problem of target identification can render them unusable. By the time an aircraft is close enough to identify its target as friend or foe, it could strike more accurately with an unguided weapon, such as the 30-millimeter cannon on the A-10, a U.S. close-support plane. Furthermore, at such close quarters an anti-tank missile may be useless because the target is within the missile's minimum launch range.

Guided weapons may sometimes be more effective than unguided weapons against such fixed targets as bridges, rail lines, and airfields, at least so long as these are uncamouflaged and undefended. But the Vietnam War suggests that even a Third World country has sufficient redundancy and rerouting and repair capability to keep its front-line forces effective in the face of deep interdiction air attacks against fixed targets, no matter whether missiles or iron bombs are used.

Similar real-world problems exist with fighter aircraft, another weapons platform that advocates of complex technology often use to advance their claims. According to Deitchman, "An aircraft like the F-4, originally designed to shoot down the enemy or drop bombs on him at close range, can be given the ability to shoot at targets from much longer range by using on-board improved radar and missiles . . . " Deitchman is wrong. The F-4 was designed solely as a nonmaneuvering interceptor, equipped with guided missiles, and the Department of Defense (DOD) tried to use it in this mode. Having great faith in the Sparrow radar-guided air-to-air missile, DOD ordered the first four models of the F-4 to be built without guns. When these aircraft were sent into combat during the Vietnam War, the result was disastrous. Because it was relatively easy to evade, the Sparrow proved to have a kill probability of only 0.08. Air combat remained centered on dogfighting, in which guns and simple heat-seeking missiles were dominant. Rapid-firing guns were quickly installed on the F-4s.

The implication of dependence on high-technology logistics systems is a return to eighteenth-century warfare.

Deitchman touches on the unfortunate logistical implications of complex weapons technology. As he notes: "Defense systems based on large-scale integrated circuitry require built-in diagnostic and test equipment simply to ascertain the cause of a failure. Beyond that, these systems cannot be repaired . . . entire assemblies must be discarded and replaced . . . the entire logistics system must be computer controlled."

Consider the effect on, say, a tank battalion that uses such systems. In tank warfare, operational mobility is very important. A commander must be able to move a tank battalion 100 kilometers very rapidly to take advantage of a gap in the enemy's dispositions, then thrust through the gap into the enemy's unprotected rear area. How are all the backup computers and microcircuit assemblies to be moved with the tanks? What happens if they are left behind? The implication of dependence on high-technology logistics systems is a return to eighteenth-century warfare, in which armies could not move far from their central storage depots. Such a reversion, in turn, could mean forgoing maneuver opportunities and being forced into attrition warfare.

Deitchman notes in his discussion the risks the new systems entail: "The new systems rely more on technology to do things that people traditionally have done. Therefore, they may be more subject to total failure because they lack human adaptability and the ability to improvise." This is quite true and its implication is profound: the new systems contradict the nature of combat. Combat is characterized above all by uncertainty and rapid change. Adolf von Schell, a German army captain in World War I, put it very well in his excellent book *Battle Leadership*: "Every soldier should know that war is kaleidoscopic, replete with constantly changing, unexpected, confusing situations. Its problems cannot be solved by mathematical formulae or set rules." Every weapons designer should know the same thing, or the weapons he designs will not be suitable for combat.

This argument about the kaleidoscopic confusion of battle has been advanced repeatedly by military reformers. Deitchman dismisses them, and he does so while inaccurately portraying their views. He says the reformers favor "slowing down our participation in the military technological revolution." In fact, the reformers favor the use of advanced technology, but insist that it be applied in militarily appropriate ways, and that it simplify, not make more complex, the soldier's task.

Again, fighter aircraft offer a good example. For shooting down other aircraft, most military reformers favor a lightweight, highly maneuverable fighter—an aircraft designed for dogfighting. It would be considerably less expensive than current fighters and therefore affordable in greater numbers. In addition, because dogfighting continues to dominate air combat, it would also be a better fighter on a one-for-one basis than any the United States is currently buying. It would use advanced technology—that is, brilliantly simplified advanced technology—in the form of extensive passive electronics and an airframe and engine designed for supersonic cruising. It would also carry advanced-technology weapons in the form of new models of the Sidewinder infrared air-to-air missile and a new, passive, radar-homing, air-to-air missile. In contrast to current practice, technology would be used to meet combat-based requirements rather than technologists' dreams, and the design of advanced-technology components would be simple and robust enough for the battlefield, not just the laboratory.

The reformers favor the use of advanced technology, but insist that it be applied in militarily appropriate ways.

I wish to make two further points about Deitchman's claim of a military technological revolution. My first point is that the term *revolution* should not be trivialized. It should be used to mean a dialectically qualitative change in the art of war. If employed, nuclear weapons could bring about such a change. It is not evident, however, that there has been a dialectically qualitative change in conventional warfare since World War II.

Such changes are in fact very rare. The nineteenth century saw one when the rifled musket invalidated the frontal tactical offensive, which was standard in land warfare. World War I produced two: the reversal of the operational mobility advantage to favor the defender, and the restoration of the tactical offensive through so-called von Hutier infiltration tactics. In World War II the operational offensive was restored to dominance when von Hutier tactics were combined with tanks and truck-mobile infantry in the *Blitzkrieg*. Neither Deitchman nor his confreres have made a convincing case that there has been a similarly dramatic qualitative change since the *Blitzkrieg*.

My second point is that weapons cannot be regarded in isolation. They function within a matrix made up of technology, unit cohesion, and tactics. Each of these elements must be conceived correctly for a military system to succeed, and their interaction must reinforce qualities that are militarily positive. Truly successful military forces have been those that have integrated all three elements to form what has been called a self-reinforcing tactical system.[1] Looking at technology in isolation is a prescription for failure to create a self-reinforcing tactical system, or for the breakdown of an existing one.

Deitchman's other underlying assumption—that we are in the midst of a general technological revolution—is also less than self-evident. Comparing the period from 1955 to 1985 with, for example, the period from 1900 to 1930, it can be argued that socially significant technological change is

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occurring more slowly today than it was then. The first 30 years of this century saw the invention or significant proliferation of the automobile, the airplane, the telephone, and the radio, all of which had profound social and cultural effects. In marked contrast, the last 30 years have seen neither the invention nor the significant proliferation of technologies that have qualitatively changed sociocultural patterns (with the possible exception of the proliferation of television).

Of course, there have been dialectically quantitative changes—the substitution of the computer for the adding machine and the card file, for example. There also have been qualitative social changes proceeding from nontechnological factors, such as the social effects of the decline in U.S. industrial competitiveness. But the notion that this is an era of technologically driven revolution should not be accepted uncritically. Perhaps it has been so widely accepted because, in broader matters as well as in the military art, we have been so busy looking at the latest technology that we have neglected to look at history, human behavior, cultural change, and the development of nontechnological ideas. Yet in the final analysis, these are usually more important. ■

NOTES:

1. John F. Guilmartin and Daniel W. Jacobowitz, "Technology, Primary Group Cohesion, and Tactics as Determinants of Success in Weapon System Design: A Historical Analysis of an Interactive Process," unpublished (1984).

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