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

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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.

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

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(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 phasedarray 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 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 of, 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

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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.

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 than 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 existing and new technology can be to improve the capabilities of our conventional military forces and to lower their cost. ■