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THE STRATEGIC AND TACTICAL IMPLICATIONS OF NEW WEAPONS TECHNOLOGIES

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James Digby[1]

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This paper deals with the impact of a new generation of nonnuclear weapons--especially precision-guided weapons--on military affairs, on foreign policy, and on arms control. For Australia, as for the United States, many of these developments will ultimately decrease the effects of distance, since many work very effectively over long distances. Thus we believe these developments have an important bearing on the fundamental assumption of past years that Australia is effectively defended by distance from many of the threats that concern other industralized nations. Moreover, the new weapons are likely to enhance Australia's ability to exercise her own military power over great distances--both her own distances and distances external to her shores.

At their best, the new weapons hold out prospects (1) for saving money, (2) for increasing stability, and (3) for reducing the brutality of war through decreasing damage to unintended targets. But these are *potential* values, and it is quite true that the importance of the new weapons has been overstated--when the reference is to the near term. Thus this paper begins by examining what has happened in conventional weapons technology.

INCREASINGLY COSTLY WEAPONS AND INCREASINGLY COST-EFFECTIVE WEAPONS

A superficial view of the new conventional weapons spectrum suggests that at one end (improved replacements for aging weapons), the trend has been for conventional weapons to get bigger, more sophisticated, more

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[1]This is an expanded version of a talk presented at the Conference on "The Defence of Australia: Fundamental New Aspects," Strategic and Defence Studies Centre, Canberra, 28 October 1976. Much of this paper is taken from our Rand Report R-1957-ACDA, *Qualitative Constraints on Conventional Armaments: An Emerging Issue*, July 1976. The report was prepared for the Military Affairs Bureau of the U.S. Arms Control and Disarmament Agency (ACDA) which proposed our participation in the Canberra Conference. The views expressed our our own and do not necessarily reflect those of ACDA or The Rand Corporation.

powerful, and sometimes more provocative--without necessarily providing equivalent advantages in terms of military effectiveness.[2] (To be less superficial one really needs to consider certain weapons in certain circumstances.) But, recently, several technical developments and their use in practical military hardware have resulted in a variety of developments at the other end of the spectrum (i.e., entirely new weapons), which suggests that past trends may be in the process of reversal. What are the most important of these new technical developments, and how are they affecting conventional weapons technology?

In the past several years, an unusually large number of significant technological changes have been introduced into practical military hardware, changes that in some cases have already resulted in what we might call quantum jumps in the performance of certain conventional weapons systems. By quantum jumps we are referring, for example, to improvements in kill probabilities on the order of 10 to 100 times, and to the ability of a pilot on the ground to control, accurately, a remotely piloted vehicle flying hundreds of miles away. Improvements such as these may well herald a period of breakthroughs in the third category above, which could result in fundamental changes in conventional warfare capabilities. This hypothesis is reflected in a recent statement by Dr. Malcolm Currie:[3]

> The technology of conventional warfare is undergoing a transformation. We are on the threshold of a new era in which evolving new capabilities will profoundly influence the nature of nonnuclear wars and the way they are deterred.

This assertion arises from recent and rapid developments in such classes of weapons as precision-guided munitions (PGMs), remotely piloted vehicles (RPVs) that can be launched from a variety of platforms, and effective mobile air-defense systems. New designs of efficient and hard-to-track cruise missiles can be either PGMs or RPVs. This overlapping of designations suggests that some definitions would be useful. A PGM can be defined as:

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[2]Those who argue that the big new weapons are more provocative do so both on the basis of their killing power and because their multipurpose design makes it difficult for a potential enemy to foresee how they will be used.

[3]U.S. Senate, Hearings Before the Committee on Armed Services on S.920, Part 6, Research and Development, 95th Cong., 1st Sess., March 7, 1975.

> A guided munition whose probability of making a direct hit on its target at full range (when unopposed) is greater than a half. According to the type of PGM, the target may be a tank, ship, radar, bridge, airplane or other concentration of military value.[4]

Note that this definition does not exclude PGMs of long range--even intercontinental range--but it does assume a mission ending in impact, with the munition generally guided all the way to impact.

An RPV is probably best defined in a very simple way:

> A vehicle that is piloted from a remote location by a person who has available much of the same piloting information that he would have if he were on board.

The term "RPV," if unqualified, usually refers to an airborne military vehicle, though the same techniques are discussed for submarines, tanks, and other vehicles.

By these definitions, some RPVs are also PGMs. Others, including some that carry reconnaissance devices or laser designators, are recoverable and are not PGMs. Both to convey the breadth of the two classes and to indicate something of the progress that has been made, some illustrative examples of PGMs[5] and RPVs are listed in Tables 1 and 2, respectively.

It is beyond the scope of this paper to examine any of these new developments in technical detail or to explore the details of countermeasures and counter-countermeasures. We shall, however, describe in broad terms what appear to be the most important technical developments and give some examples of how they have influenced military hardware.

Three technical developments seem to be of particular importance:

1. The use, in practical systems, of electromagnetic transmitters and receivers (or sensors) operating at much higher frequencies

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[4]This definition is slightly modified from one given by James Digby in *Precision-Guided Weapons*, Adelphi Paper No. 118, The International Institute for Strategic Studies (London), Summer 1975, p. 1.

[5]For brief discussions of these PGMs, see James Digby, "PGMs--Changing Weapon Priorities, New Risks, New Opportunities," *Astronautics and Aeronautics*, Vol. 14, No. 3, March 1976, pp. 36-46.

Table 1

ILLUSTRATIVE EXAMPLES OF U.S. AND SOVIET PRECISION-GUIDED MUNITIONS (PGMs)

(Including cruise missiles)

Designation	Country	Function	Range (km)	First Operational	Comments
Pave Way	U.S.	Air-dropped on surface targets	Free fall	1968	Homes on laser spot from designator
Sagger AT-3	SU	Antitank	3	1965	Optically sighted, wire guided
Grail SA-7	SU	Antiair	2	1972	Optically aimed, IR homing
CLGP cannon-launched guided projectile	U.S.	Guided howitzer	?	1980s	155-mm round homes on laser spot from designator
GBU-15 (developed from Modular Guided Glide Bomb)	U.S.	Air-to-surface	~ 110	Late 1970s	Winged 2000-lb bomb; changeable guidance module
HARM	U.S.	Air-to-surface	?	1980s	Homes on emitters (such as radars)
Condor AGM-53A	U.S.	Air-to-surface	110	Late 1970s	Can be remotely piloted by TV
Shaddock SS-N-3	SU	Surface-to-surface	400 to 900	1962	Launched against ships from surfaced submarines
Pershing II	U.S.	Surface-to-surface	730	1980s	Army nuclear ballistic missile made accurate with radar map matching
SLCM YBGM-109	U.S.	Surface-to-surface	550; 2380 to 3660	1980s	Low radar cross section cruise missile; radar homing versus ships, or terrain matching versus land targets
SS-NX-13	SU	Surface-to-surface	~ 730	?	Ballistic missile believed to have radar homing capability against ships

Table 2

ILLUSTRATIVE EXAMPLES OF U.S. REMOTELY PILOTED VEHICLES (RPVs)[a]

Vehicle	Designation	Function	First Operational	Comments
PGMs	Walleye II	Air-to-surface	1972	Guided bomb, TV picture remoted; steered through data link
	GBU-15 (developed from Modular Guided Glide Bomb)	Air-to-surface	Late 1970s	Winged 2000-lb bomb; one guidance option is remote piloting
	Aequare	Air-launched or ground-launched with rocket assist	Future	ARPA development for deep interdiction, using miniature aircraft with TV camera on board; explosive warhead option under study
	Condor AGM-53A	Air-to-surface	Late 1970s	TV picture remoted; normally antiship
Not PGMs	Aquila XMQM-105 (formerly Little-r)	Surface-to-surface	Late 1970s	Carries reconnaissance, laser designation devices; recoverable
	Compass Cope	Surface-to-surface	Late 1970s	Carries reconnaissance devices
	Praeire	Surface-to-surface	Future	ARPA development, using miniature aircraft with reconnaissance devices and laser designator
	Star	Shipboard-launched	Future	Carries reconnaissance, laser designation devices; recoverable

NOTE: Appropriate data on Soviet progress is not easy to set forth here. The Shaddock SS-N-3 and related cruise missiles may be used as RPVs at times; at least they are technically close to being RPVs.

[a]For a more complete list of U.S. RPV projects, see *Aviation Week & Space Technology*, March 17, 1975, pp. 93-94; and Government Marketing Service Publication GMS 74-9, September 1974.

than those used in the past; among other things, the consequent improvement in angular resolution makes guidance systems more accurate.

2. Continued development of microelectronic circuits (notably LSI--large-scale integrated circuits) that permit highly complex signal-processing and storage functions to take place in small, reliable, and relatively rugged devices.
3. The development of highly efficient warheads that have great destructive potential but are light in weight.

These technical developments, used in concert, have resulted in military hardware with capabilities unheard of in the recent past. For example, the development of practical airborne lasers that use frequencies so high--i.e., wavelengths so short--that they are typically just below the spectrum of visible light, has made it possible to guide weapons with angular accuracies approaching those of a high-powered rifle. When the signals reflected from a laser-generated spot that an individual has pointed at a target are processed by microelectronic circuitry, a very compact and effective guidance system can be used to steer a missile to within a few feet of a target from a launch distance on the order of 10 mi. It is just this combination that is being used in the new laser-guided Maverick antitank weapon system. But Maverick carries a very heavy warhead for its task, about 130 lb, and the whole round weighs about 460 lb. If the third development cited above, namely new efficient designs for high-explosive warheads, had been incorporated in the design, a missile with similar lethality, but significantly lighter weight, could have been built.

New types of RPVs (see Table 2), not many years from full-scale testing, will take advantage of new technologies to permit the construction of light and quite small vehicles by comparison with earlier-generation RPVs such as Condor. These systems, which could be launched from cargo-type aircraft, from the ground, from vehicles, or from ships, will have a remote operator who will continually monitor the performance and progress of the vehicle; detect, discriminate, and choose correct targets; and override the automatic guidance if necessary. The fact

that the vehicle is guided during its terminal phase makes it relatively insensitive to conditions at the time and place of launch, provided a data link can be maintained between the vehicle and its remote pilot.

The potential importance of some of these technological advances was brought dramatically to world attention[6] by their use during the late stages of U.S. involvement in Vietnam and during the Arab-Israeli War of October 1973. For example, in the last days of the war in Vietnam, laser-guided bombs having CEPs on the order of 10 to 20 ft were used, as compared with approximately 1000 ft for unguided bombs. This resulted, for certain targets, in an achieved target kill in two or three sorties, whereas 100 or more had been required for unguided bombs. The Arab-Israeli War of October 1973 provided many more examples of the operational implications of advanced weapons. There we saw how shaped-charge warheads made relatively small antitank weapons--notably, the Soviet Sagger missile and the unguided RPG-7 rocket--very lethal against Israeli tanks even though these weapons were quite small in size and were carried by individual Arab soldiers or mounted on relatively small vehicles. The shoulder-launched Grail heat-seeking antiaircraft missiles (SA-7) caused some changes in Israeli air tactics, while other elements of the Soviet-built mobile air defenses, such as the ZSU-23-4 radar-directed gun and the SA-6 heat-seeking missile, provided surprisingly (to the Israelis) effective air cover for the advancing Arab ground forces. Some of the weapons used in the October War were early models and underdesigned for their tasks; nonetheless, Israeli officers reported that their sheer numbers presented Israeli forces with an exceedingly

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[6]Note, however, that many of the *principles* of currently successful weapons have been around for many years. The Germans developed the wire-guided X-7 "Ruhrstahl" antitank missile in World War II and the French anticipated the Sagger and TOW missiles with their SS series of wire-guided antitank missiles. Wright Field engineers developed the AZON and RAZON steerable bombs, and these were used against bridges by the USAAF in 1944. Additionally, most of the air defense missiles produced since World War II have been steered all the way to their targets. What has changed in many cases is that new technical developments have permitted practical applications of the principles in the development and production of new weapons that perform much better than their anachronous predecessors.

dangerous threat.[7] These examples represent what might be the leading edge of a wave of quantum jumps in conventional weapon performance.

Two other important factors regarding these quantum jumps in performance are that (1) many of the new weapons are relatively inexpensive, and (2) many of them are relatively simple to operate. Note that we say *relatively* inexpensive and *relatively* simple to operate. Many of the new weapons are fairly sophisticated and can only be called inexpensive relative to manned systems or earlier guided missiles[8] or to the cost of the total number of other weapons that might be used to achieve an equivalent effect. Or they may be inexpensive relative to the target they are designed to kill. But they are not too expensive to preclude an abundant supply--and the possibility of abundance accounts for much of the significance of these newly produced weapons, as became clear in the Arab-Israeli War of October 1973. Thus the new technology has already been used in the mass production and mass use of precision-guided munitions that were simple enough to be operated by units that had little tradition of dealing with complex systems--albeit the Arab soldiers who used them were specially selected and highly trained.

QUANTUM JUMPS IN COSTS OF CERTAIN SYSTEMS

On the other side of the coin, many new and improved conventional weapons systems represent quantum jumps in cost. In each branch of the

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[7] There are also numerous examples on the Israeli side that highlight the pace at which new systems are now being introduced into military forces. Dr. Currie cites ten examples of systems that were not operational a decade earlier. Most of these were precision-guided air-to-ground weapons: Walleye, a 1967 TV-guided glide bomb; HOBOS, a 1968 electro-optically guided bomb; Maverick, a 1973 electro-optically guided weapon; Shrike, a 1964 antiradiation missile; and air-to-air weapons: AIM-9D and AIM-9G, 1964 and 1973 versions of the Sidewinder; AIM-7E-2, a 1964 version of the Sparrow; and Shafrir, a 1969 Israeli development based on Sidewinder. (From U.S. Senate, Hearings on S.920, Part 6, March 1975, cited on p. 2655.)

[8] Consider, for example, the YBGM-109 tactical cruise missile that has a target cost of $525,000 1975 dollars in contrast to the somewhat similar Bomarc air-defense missile that would cost about $2.3 million if 1955 dollars ($667,000) were converted to 1975 dollars. Bomarc, originally estimated to have a unit cost of only about $40,000 because of its "simple" ramjet engine and "simple" air-to-air radar seeker, was plagued with many problems besides underestimated costs.

military, several of the weapons systems whose development is given the highest priority are significantly more expensive than the existing systems they replace. This is especially so where weapons systems have multiple functions and are an integral, interwoven part of high-performance vehicles intended for use directly in the arena of combat. Consider a few such items in our catalog of conventional weapons: deep-penetration fighter-bombers, new tanks, and nuclear-powered aircraft carriers. The latest models of some of these weapons systems, although very capable, cost a great deal more than the systems they were designed to replace. For example, a single new nuclear-powered aircraft carrier costs about $1.5 billion as compared with a price tag of about 620 million 1975 dollars (or 310 million then-year dollars) for aircraft carriers in the mid-1960s. Whereas an F-4 cost about 10 million in 1975 dollars (5 million then-year dollars in 1965), the F-15 designed to replace it costs nearly $15 million. Indeed, as pointed out, a cursory look at the dominant features of some of our newest conventional weapons systems (a number of which fall into the category of improved replacements for aging weapons) suggests that many of these weapons are inexorably getting bigger, more sophisticated, more powerful, more provocative, and more expensive--without necessarily providing us with as great an edge over the Soviet Union as might result from more units of simpler design.[9]

These considerations are not made easier by the prospects that big, expensive systems may serve as a necessary platform for small, cheap systems. The GBU-15 glide bomb can be carried by an F-15, for example. The F-14 aircraft with a Phoenix air-to-air missile can be carried by a Kitty Hawk class (1961) carrier giving a considerable advance in capabilities. Such hybrid systems will be particularly necessary during the next 10 or 15 years.

Figures 1, 2, and 3 on the following pages indicate the consistency with which the cost of each of three basic kinds of military hardware

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[9]"Simpler design" here means that the penetration into the combat area is done by the simplest possible weapons; often this means that they will be designed for the main expected circumstances, not for all conceivable ones. Their technical design would not be so advanced as to add greatly to initial cost or maintenance.

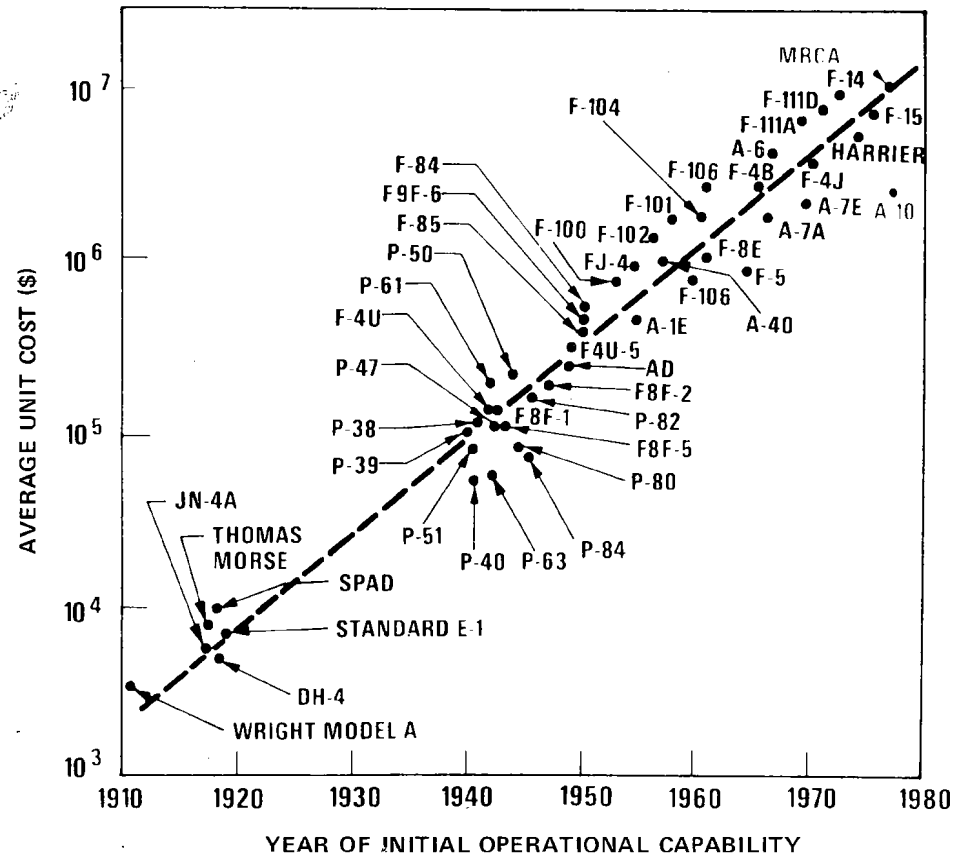

Fig. 1 — Unit cost increase with time – Tactical Aircraft

has risen in recent decades.[10] (Note that the ordinate in each figure is a logarithmic scale.) With regard to these figures, Augustine comments that

> The unit cost of major items of military hardware has been increasing at a significantly faster pace than the DoD budget itself or, for that matter, the Gross National Product.... [If the trends continue] we will reach a point in the year 2036 where the Defense Department will literally be able to afford only one aircraft. [p. 34]

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[10] Figures 1, 2, and 3 are taken from Norman R. Augustine, "One Plane, One Tank, One Ship: Trend for the Future?" *Defense Management Journal*, Vol. 11, No. 2, April 1975, pp. 34-40. Augustine, now Under Secretary of the Army, does not specify that the costs in each of these figures are "then-year" procurement costs but presumably they are. We have corrected an apparent error in the ordinate of Fig. 3 by multiplying the *Journal* figures by 10.

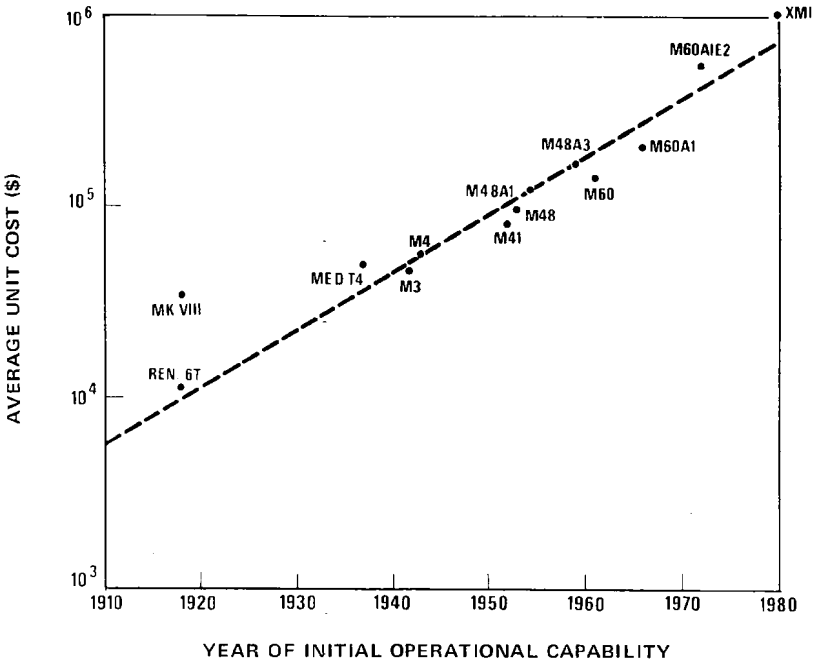

Fig. 2 — Unit cost increase with time – Tanks

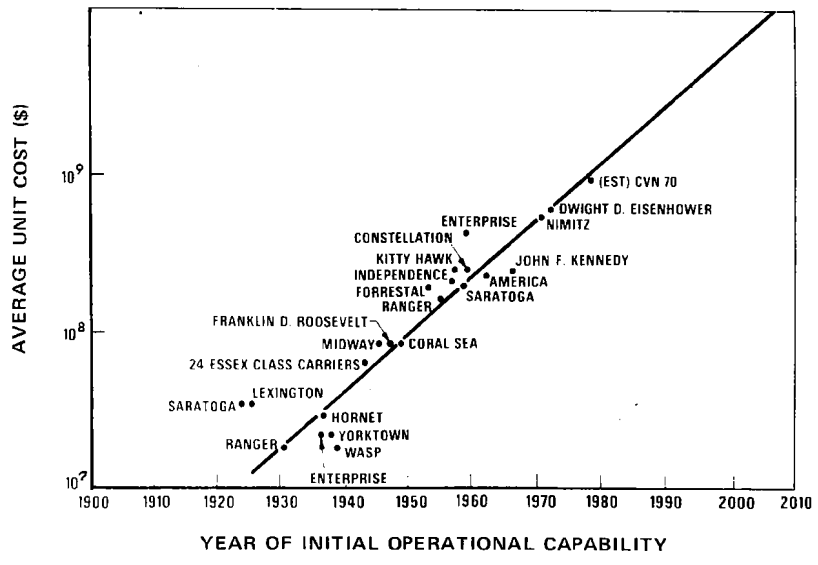

Fig. 3 — Unit cost increase with time – Aircraft Carriers

He then concludes his article with

A Glimpse at the Future

> It is inevitable that the past trend in rising equipment costs must decelerate and that numerical sufficiency cannot indefinitely continue to play a secondary role in qualitative superiority. Nonetheless, selective qualitative gains remain an essential goal, with especially high leverage being achieved through research and development dedicated to the reduction of manpower and other support demands with the efficiencies thereby realized being transformed into additional fighting elements. Thus, in the years ahead, we could profitably shift the focus of our R&D from near-total concentration on increasing performance to a more balanced attack which includes, as one element, a major assault on support costs. [p. 40]

Calculations of cost and effectiveness that compare the value of different weapons systems are exceedingly difficult and, at best, subject to many qualifications and arbitrary assumptions. There are, of course, experts who state a very impressive case in favor of each of the complex systems up for decision; these are a main feature of service testimony at Congressional hearings. On the other side, three opposing arguments seem relevant:

(1) In the Brookings Institution review of the FY 76 budget, it is pointed out that a nuclear-powered aircraft carrier costs about 50 percent more than a comparable conventionally propelled carrier; thus three conventionally powered carriers can be acquired for the price of two comparable nuclear-powered vessels.[11]

(2) In his recent book *On Watch*,[12] Admiral Elmo P. Zumwalt said that a patrol frigate can perform certain missions as well as a nuclear-powered cruiser. But for the price of one nuclear-powered cruiser, the United States could buy five patrol frigates.

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[11] Barry Blechman, Edward Gramlich, and Robert Hartmann, *Setting National Priorities: The 1976 Budget*, The Brookings Institution, Washington, D.C., 1975, pp. 107-108. The costs referred to there include only construction cost plus 30-year fuel cost. Full system cost comparisons are more complicated.

[12] Quadrangle/The New York Times Book Company, New York, 1976, p. 102.

(3) Dr. Richard L. Garwin, an IBM Fellow at the Thomas J. Watson Research Center and consultant to the Department of Defense, was quoted in *Forbes* (April 15, 1975, p. 23) as saying that "While the F-15 can beat the improved MiG-21 on a one-to-one basis, an equal-cost force of MiGs would just eat up the F-15 because the advantage of numbers is so great." The same article estimated that the price of one F-15 would buy seven MiGs in the United States. (This statement--which may not quote Garwin in full--is more interesting as an example of perceptions than as analysis, since it evidently ignores operating costs and compares the F-15 with a MiG of unspecified vintage without saying anything about types of armament.)

Thus, for the foreseeable future, a major dilemma for the United States will be the need to reconcile demands brought on by a changing and numerically impressive threat with pressures for nonmilitary programs, while allocating military funds between expensive systems in smaller quantities and cheaper systems in larger quantities.

INCREASED IMPORTANCE OF THE SUPPORTING STRUCTURE

For the new precision weapons, the supporting structure in which they are used may be crucial to their success in a large-scale war. The control over this structure has some major implications for arms limitations and for big-power control over arms transferred to smaller powers. Yet it is commonly overlooked as analysts describe the great improvements approaching "one shot, one kill" that might apply in one-on-one engagements. In a large-scale conflict, the characteristics of individual weapons, taken one-on-one, could be dominated by the way thousands of weapons of several types are made to work together in a mutually supportive way.

This supporting structure has several elements: (1) the advance reconnaissance that localizes targets, (2) the target acquisition system that identifies individual targets right up to trigger-pull, (3) the command function that allocates and marshals the new weapons to the place where they are needed most, (4) the combined-arms partnership that protects the crews of the new weapons while they do their jobs, (5) the transport (perhaps laterally to a front) of the new lightweight but powerful weapons systems, and--most important--(6) the network that replenishes expended weapons.

The importance of this supporting structure can be appreciated when one considers that a brigade commander in World War II might do his job from a situation map that showed where six enemy motorized rifle battalions and three tank companies were located. In 1980, he and his staff might need to keep track of 500 to 1000 individually moving and independently powerful squad-size units. To fully exploit his PGMs, each of these targets would have to be acquired on an individual basis.[13]

For a large-scale war, along NATO's Central Front, for example, or along the Sino-Soviet border, the decisive aspect might turn out to be the battle to destroy the enemy's supporting structure. Thus each of the six elements named will need to be as invulnerable (or nondisruptable) as possible. For instance, U.S. air commanders would need to ensure that replenishment supplies of Maverick missiles (or their successor) would continue to arrive at loading points during battle, and that the quantities on hand and pathways for resupply were designed to hold up under the attacks that would undoubtedly be pressed against them.

For a small-scale war, where the numbers of targets presented per day were in the tens rather than thousands, the single-shot kill probability or one-on-one weapon performance might be the dominant factor. But there is an intermediate case of considerable interest in connection with the consequences of arms transfers to the nonindustrial countries, where recipients might acquire hundreds of the weapons themselves, but not be capable of dealing with all elements of the supporting structure. Another war in the Middle East might well be of this intermediate size. As a part of U.S. policy on arms transfers to the Middle East, it is important to think through the extent to which our government could exercise some continuing control over the large-scale employment of these arms, such as by controlling reconnaissance or replenishment functions essential to the full exploitation of the weapons.

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[13]Some senior American officers, having sized up this situation, are now calling on the research and development community to improve nonnuclear weapons with area coverage. This is of considerable importance with respect to arms limitations, since it might make constraints on weapons employment designed to reduce collateral damage more difficult.

IMPORTANCE OF INCREASING MANPOWER COSTS

Despite order-of-magnitude increases in costs of some weapon systems, that portion of the DoD budget devoted to procurement of military equipment has been steadily shrinking. In 1955, 41 percent of the defense budget--$14 billion--was spent for aircraft, ships, tanks, and other military hardware. Twenty years later, in 1975, the absolute amount was almost the same--$14.8 billion--but procurement of these items accounted for only 18 percent of defense spending. During that same period the cost of military personnel increased from $10.6 billion to $25 billion even though the number of persons in service decreased from 3.2 million to 2.2 million. Put another way, the average annual cost per person in the armed forces increased from $3350 in 1955 to $11,500 in 1975, with the greatest rate of increase occurring after 1970 as a result of the transition to an all-volunteer force.

The Soviet Union maintains active armed forces almost twice as large as those of the United States--4.2 million men and women, of whom about 2 million are conscripts. No matter how poorly paid a Soviet conscript may be, the forces are large, and although Soviet authorities may not be as strongly motivated to conserve human resources as their American counterparts, they cannot be indifferent to the opportunity costs of devoting so much manpower to the military.

High manpower costs have several implications for force planning. In some cases, by spending more on equipment, total costs could be reduced by increasing the productivity of each man. For support units that may imply the introduction of labor-saving machinery. For combat units it means procuring more accurate and more lethal weapons to increase firepower while holding manpower constant. It may also imply designing new equipment to reduce manpower requirements throughout its entire life-cycle. Perhaps crew size could be reduced, or higher reliability could be designed into the equipment so that fewer maintenance personnel would be required.

More relevant to the present discussion is the possibility that investment in one relatively expensive guided missile may eliminate the need for several hundred iron bombs or artillery shells and the manpower and overhead expenses involved in transporting, handling, storing, and

loading them. A decline in the need for support personnel should have a beneficial effect on teeth-to-tail ratios, particularly in the ground forces. Thus, one could envisage an increase in the number of combat units with no increase in military personnel or manpower-associated costs.

Adding a new combat unit does imply a substantial investment. A U.S. armored division force equivalent (the division and all combat, combat support, and combat service support units required within a theater of operation to conduct combat operations) has a nonrecurring cost, excluding RDT&E, of approximately $1 billion. This cost is for initial procurement of equipment, supplies, and spare parts but not missiles or ammunition. The annual recurring cost is about $600 million of which perhaps 75 percent is for military personnel. Increasing the annual outlay for ammunition and missiles (about $30 million) by a factor of two would increase recurring costs by about 5 percent. Thus, even without possible savings in manpower, the incremental cost attributed to equipping the division with the latest in conventional munitions would not be great--though it might come from tight budget categories.

These are factors that must be borne in mind in considering how qualitative constraints might impact on force structures, since it seems clear that the United States cannot afford to be handicapped, particularly in attempting to maintain the balance in Europe, by foreclosing ways that might make each man count for more.

IMPLICATIONS OF THE NEW TECHNOLOGY OF PRECISION GUIDANCE

The recent and rapid technological developments indicated in the previous sections have resulted in a variety of new weapons systems that are quite precise--both in hitting intended targets and in avoiding unintended targets. Many are quite efficient in terms of kills per pound or kills per dollar when operated under ideal conditions. But conditions are not always just right, and this section on their implications treats them not only at their best, but also mentions the possibilities of poor performance. We discuss, below, the implications of precision-guided munitions (PGMs) and remotely piloted vehicles (RPVs) by expanding on eight summary points.

1. *Many PGMs and RPVs appear to represent a quantum jump in military effectiveness (even when compared with quite expensive alternative systems that do not use precision guidance). However, there are some situations in which their effectiveness is limited--and those should be faced squarely.*

Perhaps the great advantage of PGMs--if they are used under the conditions for which they were designed--is best summarized in the following statement:

> Accuracy is no longer a strong function of range; if a target can be acquired and followed during the required aiming process, it can usually be hit. For many targets hitting is equivalent to destroying.[14]

Notice, though, that even this brief statement implies that a number of things can go wrong. For one, the process of target acquisition may not be easy. Even for targets that are acquired, it may be difficult to track the target with presently deployed equipments, most of which

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[14] Slightly modified from James Digby's *Precision-Guided Weapons*, Adelphi Paper No. 118, The International Institute for Strategic Studies (London), Summer 1975, p. 4.

are visual or near-visual wavelengths. Bad weather, battlefield smoke, camouflage, or other obscurants may prevent tracking at any but very short ranges. In some cases, efficient employment depends on a good command-control system, and some current systems are better known for their deficiencies than for their excellence. Countermeasures can also be taken against the PGM or its crew--some technical in nature and some tactical, such as evasion by the target during the missile's flight or attacks on the PGM crew while it is trying to guide the missile. These targeting and environmental difficulties, which can be particularly severe for long-range PGMs and RPVs, must be overcome before these weapons can be usefully employed in a wide variety of operating conditions. In some cases, this may be accomplished through technological improvements in the supporting structure or by redesigning tactics to exploit them effectively; in others, it may be more difficult.

In spite of these difficulties, in many situations PGMs and RPVs will perform well enough to make a major difference.

2. *Many PGMs and RPVs are relatively cheap--cheap to develop, to procure, and to operate. But to understand the full cost implications, some context is needed.*

As is shown in the selected examples of PGMs and RPVs in Table 3, the new weapons range in cost from under $5000 for antitank missiles such as TOW to an estimated cost of over $500,000 for a long-range cruise missile. Those costs may seem high compared with the cost of an artillery round ($100) or a 2000-lb iron bomb ($1000), but they are low relative to the cost of their targets. The latest version of the M-60 tank costs almost $600,000; almost any kind of a capital ship costs over $100 million; and a nuclear carrier fully equipped with 90 aircraft represents an investment of over $2 billion. Thus the force-wide cost of adding PGMs can appear high or low, depending on how many must be bought for each expected kill, and the usual cost comparisons are apt to be misleading unless they are placed in an operational context.

Table 3

ILLUSTRATIVE PGM AND RPV COSTS[a]

Weapon	Unit Cost[b] (1975 $)	Production Quantity
TOW	3,000	150,000
Dragon	5,000	80,000
Maverick (TV)	22,000	30,000
Sidewinder (AIM-9L)	37,300	1,800
Condor	333,000	162
Harpoon	436,000	785
SLCM (strategic)	525,000 (est.)	---

[a]For a discussion of missile costs in general, see Appendix A.

[b]Costs of fire-control systems and launchers are not included except for Dragon.

Most PGMs used under the conditions for which they were designed have higher kill probabilities than the unguided weapons they replace.[15] Under good conditions, one Maverick is clearly more likely to hit and destroy a target than one iron bomb, but whether one Maverick does the job of 10, 50, or 1000 iron bombs depends on the tactical situation--the effectiveness of the defenses, weather conditions, time of day and sun angle, pilot skill, and a number of other factors. Consequently, while Maverick may be cheaper than the number of bombs required in one situation, it may be more expensive in another, and may not be usable at all in some situations.

[15]To date, most PGMs have been designed to attack point targets (individual tanks, ships, aircraft, bridges, etc.), and our discussion of cost-effectiveness generally relates to point targets. This is not to say that some types of precision-guided weapons would not be useful against area-type targets; Rockeye and the German weapon Strebo are examples of PGMs designed especially for such targets. Other PGMs for area-type targets are likely to be designed in the future. In any case, since many battlefield targets are of the area type (e.g., troop concentrations, vehicles on the move or parked, and repair facilities), there will continue to be a need for weapons appropriate for these types of targets, both PGMs and non-PGMs.

Assuming for the moment, however, that for certain circumstances one could estimate that one Maverick at $22,000 is equal to 50 2000-lb bombs at a total cost of $50,000, he would still not have a valid comparison. In both cases, the costs that dominate are those of the aircraft, aircrew, airbase, logistics structure, and training establishments needed to ensure that the weapon is delivered. Moreover, in most situations the Air Force has felt the need to send along a number of supporting aircraft with the PGM carriers to aid in defense suppression. The real savings would come from the reduction in sorties required to destroy the target. One sortie with four Mavericks plus four supporting sorties, compared with 60 sorties with unguided bombs, means reductions in crew losses, aircraft attrition, fuel, maintenance, support, and training. Thus a comprehensive fixed-effectiveness cost comparison would favor PGMs decisively in those situations favorable to their use. But if the weather were bad, but not so bad that it would ground all aircraft, Maverick might not work at all, and this would have to be taken into account statistically and by keeping backup systems.

At the high-cost end of the spectrum in Table 3 are such highly sophisticated weapons as the Condor and the sea-launched cruise missile (SLCM), which have both high-development and high-production costs. The SLCM, for example (in both tactical and strategic versions), is now estimated to cost almost $1 billion for RDT&E, and over $500,000 per unit in production. Would this be an excessive price for a missile capable of finding and destroying a surface ship at a range of up to 2000 mi? When one considers the value of a ship relative to the SLCM, the tradeoff appears advantageous to the PGM even if several had to be fired. But a more complete analysis would require an examination of alternative ways to do the same job. For example, what would be the comparable cost if airplanes with unguided weapons were used?

Whether widespread deployment of PGMs would actually result in net cost savings is a different question. Force planners may operate on a fixed-cost basis (i.e., fixed procurement budget) rather than on a fixed-effectiveness basis, and effectiveness would increase as expenditures remained constant. Net costs are found by considering unit costs, such as those in Table 3, in the context of a force structure. To do

this, more complex cost consequences must be considered, including whether one must have expensive supporting activities and accompanying forces (as mentioned above for Maverick) or backup forces for cases in which PGMs do not work well. Nonetheless, the evidence points to substantial efficiencies where PGMs can be fully exploited.

3. *Many of these new weapons could be developed and manufactured using existing facilities and current production methods. Others, which may be very useful, require advanced industrial facilities.*

Consider first the laser-guided bomb (LGB); it requires only a pulsed laser designator, with a simple quadrant detector and a "bang-bang" control system on the bomb.[16] This equipment is all quite easy to develop and manufacture. It undoubtedly could be or has been built in the Soviet Union, and is probably within the capabilities of several Third World countries as well. Another example of a precision-guided weapon that has already been widely developed and manufactured in several versions is the semiautomatic wire-guided missile. The rocket motor technology and the techniques for unreeling the wires (that carry the guidance signals) out the rear of the missile were developed by the Germans during World War II. The tracking and guidance system typically uses inexpensive flares or light beacons on the missile as infrared sources. Both the infrared tracker (located at or near the launcher) that follows these beacons and sends guidance signals to the missile, and the missile system itself, can be easily fabricated using what is now standard technology.[17] Furthermore, the development and manufacture

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[16]This is a simple silicon detector that measures the laser energy reflected from the target in each of its four quadrants and sends steering signals to the fins on the bomb to keep the laser spot centered in the detector, and thus keep the bomb directed toward the target. The control system has only two positions for each fin, thus the term "bang-bang."

[17]In a typical design, the infrared tracker employs an optical encoding reticle, infrared detectors made from silicon or germanium, electronic amplifiers, and decoding circuitry. Depending on the instantaneous position of the target on the reticle, the infrared detector

of both of these types of weapons can be accomplished in laboratories and factories that are externally indistinguishable from a television factory.

On the other hand, some of the other new weapons are rather difficult to develop and manufacture: some require a high degree of technology and some require special manufacturing techniques. An example is IR Maverick (which can be used at night and in limited-weather attacks against targets such as tanks, trucks, and APCs). This new weapon system uses high-technology forward-looking infrared (FLIR) sensors for target acquisition, and takes advantage of new trimetal (HgCdTe) detector technology in the imaging infrared guidance unit in the missile itself.[18]

It seems clear that the United States holds the lead, at least for the moment, in many of these new technologies that have great possibilities for increasing military capabilities. For example, it is doubtful if the Soviets have yet developed high-quality FLIR sensors. Moreover, it should be remembered that the new technologies have no military worth in themselves. It is only when they have been engineered into military

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develops signals that indicate the displacement of the target from the missile flight path; these signals are then sent to the missile through the wires to keep it on target. Such a system can be operated from the ground, or from a carrier such as a tank, a weapons carrier, a jeep, or even from a helicopter.

[18]HgCdTe detectors have largely replaced doped germanium detectors for application in FLIR sensors, primarily because they require less cooling, liquid nitrogen temperatures being adequate. They also have a much higher infrared absorption coefficient, and so may be made much thinner; correspondingly, they have larger quantum efficiencies. Their impedance is low, and response time is in the microsecond to nanosecond region. The fabrication of these detectors, together with the associated preamplifiers, particularly in the high-density arrays required for FLIR sensors, requires, however, very specialized technology. This technology involves, among other things, advanced photolithographic techniques; it has evolved over the past several years at a few industrial laboratories in the United States; it is highly competitive and protected by tight industrial security. The problems are aggravated in the missile application because of strict cost limitations. (See R. B. Emmons, S. R. Hawkins, and K. F. Cuff, "Infrared Detectors: An Overview," *Optical Engineering*, Vol. 14, No. 1, January/February 1975, pp. 21-30; and H. Levinstein and J. Mudar, "Infrared Detectors in Remote Sensing," *Proceedings of the IEEE*, Vol. 63, No. 1, January 1975, pp. 6-14.)

hardware which can be mass produced that their full potential can be realized.

Thus, a major consideration affecting decisions regarding qualitative constraints is the degree to which the capabilities of the United States (and the rest of the industrialized Western world) to mass-produce large quantities of high-technology weapons (at relatively low cost) can be relied on to help offset the quantitative superiority of the Warsaw Pact forces.

4. *There may be important consequences for logistics deriving from the small size but great effectiveness of the new weapons.*

Many of these new weapons tend to be both small and effective in comparison with (a) the target they are designed to attack, (b) the systems they replace, or (c) much larger and more expensive unguided weapons.

For example, the TOW missile is 15 cm in diameter, 117 cm long, and weighs 23.6 Kg including its protective container, which serves as a launch tube. The warhead itself, a shaped-charge design, weighs only 3.6 Kg. Yet this missile can destroy or disable a modern tank many times its size, and weighing more than 60 tons, at ranges up to 3750 m. Functionally, this missile, with its launcher, replaces the much bulkier and usually less-effective 106-mm recoilless rifle. Similarly, a Stinger surface-to-air shoulder-fired missile that is less than 10 cm in diameter, 152 cm long, and weighs 13.4 Kg can destroy a fighter aircraft flying within its speed and range envelopes--a job that normally would have required many rounds of antiaircraft gunfire.

In the case of a longer-range weapon, the Navy's YBGM-109 sea-launched cruise missile is designed to be launched from standard-sized torpedo tubes (as well as from A-6's or ships). It is likely that the "tactical" SLCM will be able to disable or destroy a variety of major surface combatants, and that the "strategic" SLCM will be able to attack a variety of high-value on-shore targets, such as power plants, bridges, and POL facilities at ranges of 1400 mi or more. In performing these

tasks, its predecessor was the A-6 aircraft armed with nonprecision weapons, and the platform was a CVN instead of an SSN or frigate.

Because many of these new weapons are small in size and high in effectiveness, there is the possibility that the weight and volume of munitions that will have to be hauled to the battle area to accomplish a given task will be considerably less. This would have a major effect on the logistics of replenishment (although the probability of much-increased consumption rates needs to be factored in). For example, for air-delivered weapons, if sorties can be cut, then so can the number of aircraft required, together with maintenance and associated supplies. This "ripple effect" could thus magnify by severalfold the reduction at the cutting edge: Not only are there savings in direct support for the weapons and their crews, but additional savings accumulate at each echelon as the support units themselves shrink and, in turn, need less support from units farther back. This ripple effect needs to be carefully studied, partly because the prospect of higher consumption rates for a shorter time means a quite different logistics design, and partly because the logistics system may be a prime target itself. But there still may be a net savings even after the costs incurred by the added personnel required for PGM and RPV maintenance and supply have been taken into account.

5. *Many of the new types of weapons can be moved quickly and in quantity to the places where they are needed most.*

Because of their small size and light weight, many of these new weapons could be moved to defend an area where an offensive threat was developing. This, of course, would require that necessary transport be available, together with tactics to exploit the combination. For example, antitank weapons such as TOW and Dragon and antiaircraft weapons such as Stinger could be transported quickly and in quantity by helicopter or small aircraft to a threatened point where an armor and air attack was developing; some army planners also talk of transporting a lightweight vehicle (such as the XR-311 Dune Buggy) to carry them into combat. By contrast, this would not be possible for tanks.

It would be necessary to develop new tactics for this kind of use, since they would differ considerably from those used in traditional defenses against tanks. The attacker's tactics would also quite likely be modified both to exploit his PGMs and to defend against opposing PGMs. Thus while these complications plus some others involving command structure and reliable communications would have to be overcome, the possibility of getting a larger quantity of more effective defensive missiles into the action should be very helpful along NATO's Central Front, given the numerical imbalance there.

6. *Many of the new PGMs and RPVs are particularly useful to a defender.*

It is quite complicated to discuss whether a given weapon is advantageous to the "defense" in contrast to the "offense." Along a wide front, an offensive involves defensive holding over most of its length. Especially when forces have mostly short-range PGMs, the success of an offensive move will depend on being able to defend a vantage point once it is taken. However, several things can be said about the defensive value of the new-generation weapons. First of all, most currently available PGMs are specifically designed to be primarily defensive. This includes antitank and antiaircraft guided missiles. Second, target acquisition is the key to successful use of most of these weapons, and it is much easier for a defender to remain concealed than it is for the attacker, who is moving through (or flying over) unfamiliar territory, and who has no opportunity to prepare positions. The very nature of this kind of warfare makes concealment extremely important.

It will probably be easier to conceal relatively small units--perhaps as small as a three- or four-man individually mobile squad. With PGMs, such small units can represent a great deal of firepower. Moreover, the act of concentrating forces, classically so necessary for an offensive thrust, would be likely to attract the attention of reconnaissance systems. This may make such thrusts harder to bring off, because once the concentrated forces are spotted and tracked, great numbers of PGMs and RPVs might be brought to bear on the thrust.

7. *Even the largest PGMs and RPVs (e.g., the sea-launched cruise missile) can be hard to detect and their carriers can be effectively disguised. They can be launched from a wide variety of platforms without affecting terminal accuracy.*

A consequence of the concealment possibilities will be the need for better reconnaissance systems and for real-time fusion of intelligence from many sources. During peacetime, security requirements have been allowed to block effective, fast transfer of some kinds of intelligence. This may have to be changed because of the threat presented by concealable PGMs and RPVs. A second consequence--of great importance to the monitoring of nuclear as well as nonnuclear agreements--is that "national means of verification" just will not be adequate a decade from now. Finally, from the last part of the statement, one can expect that weapons systems and launch platforms will increasingly be treated as independent designs, independently developed and procured. When a transport aircraft or cargo vessel may carry either cargo or operational missiles or both, changes in tactics are likely.

8. *There are important political consequences stemming from the new weapons.*

Perhaps the most important political consequence is the possibility of lowering the damage to nonmilitary targets.[19] Since the new missiles can be made to be quite precise, they can disable their intended target without damaging nearby civilian installations; civilian casualties can thus be minimized.[20] This opens up the opportunity for agreements, or implicit understandings, that would strictly limit civilian damage in a conventional conflict. Abiding by such an undertaking may be an efficient way for military forces to operate, as they did for hundreds of years, as well as being morally attractive and mutually beneficial to both adversaries.

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[19]For further discussion see Johan Jørgen Holst and Uwe Nerlich, eds., *Beyond Nuclear Deterrence: New Aims, New Arms,* Crane, Russak and Co., New York, 1976. See especially the chapters by Holst, Digby, and Wohlstetter and Rowen.

[20]This effect, however, is mitigated by the constantly and rapidly increasing urbanization of the developed countries, which leads to the colocation of many military targets with civilian communities.

Precision is particularly important in a nonnuclear conflict between the superpowers, since one of the most crucial aspects of such fighting is the signal content of the actions undertaken, i.e., what these actions mean in terms of willingness to escalate or conciliate. In other words, the military commander could offer to the political leadership a number of options. One of these could be selected to fit the tone and intent of the political discourse. (For example, a submarine base could be attacked if it had supported raiders who had torpedoed friendly ships.) The objective would be to get the opponent to cease his actions. But this matching of target to objective would be obscured if substantial unintended damage occurred, in which case an unwanted widening of the conflict might occur.[21]

A second political consequence is that the deployment of very effective nonnuclear weapons can reduce the necessity for using nuclear weapons in certain cases, thus raising the nuclear threshold. This is not to say that nuclear weapons would not be much more effective against some targets. But precision guidance greatly increases the set of targets that can be dealt with effectively with nonnuclear weapons, and there will be less need to compensate for inaccurate delivery by increasing the warhead's lethal radius. Nor does this say that the Soviets will see the choice between staying with high explosives and "going nuclear" in terms of Western-style calculations.

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[21] Note that a posture that includes a strong and flexible conventional capability signals *in advance* an intent to try to settle matters without resorting to nuclear weapons. But it need not convey certainty that they would not be brought to bear at some stage, especially if nuclear pre-emption were suspected.

For Australia's future defense plans all of these factors seem to indicate substantial departures from the assumptions of past years. It is our feeling that the re-examination which the Strategic and Defence Studies Centre is making with this set of papers is particularly well-timed. Australia's neighbors can increasingly dispose of powerful military forces, and her great distances are of lessening significance. We in America are now making such a re-examination, and Hedley Bull's comment that the present vector in American strategy is not necessarily toward isolationism was--in our view--a correct perception. Rather, we suspect that new kinds of multilateral collaboration in security--involving many factors besides the military--will flourish, collaborations not along fixed alliance lines, but more ad hoc, forming and re-forming to meet serious problems. These collaborations will stress nonnuclear defense, arms transfers, economic matters, and political factors. These are problems on which joint intellectual work by Australians and Americans can be very influential.