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HARVEY BROOKS

The Military Innovation System and the Qualitative Arms Race

FOLLOWING THE CONCLUSION of the first round of SALT negotiations in June of 1972, a limitation on the rate of technological progress in weapons systems is emerging as a central problem for the future of arms control. In SALT I, technological progress threatened to overtake the slow pace of the negotiations. At the start of the negotiations, for example, the multiple independently targetable warhead (MIRV) was in its later development stages, but by the time the agreement had been concluded, it was a fairly well-tested weapon, ready for full-scale deployment in the Minuteman system and in the Poseidon missile for the Polaris submarines. MIRV potentially multiplied the destructiveness carried in a single missile to the point where any agreement to limit the deployment of offensive strategic missiles was made much more difficult. Fortunately, technological progress in ballistic-missile defense did not make obsolete an agreement on ABM limitation, but even here the emergence of possible exotic ballistic-missile defenses (such as high power lasers) almost threatened agreement and did complicate the negotiations. Since SALT, a whole panoply of new weapons possibilities has emerged into public view and is being vigorously pursued in the United States: the Trident submarine, the B-1 bomber, the long-range cruise missile, the maneuverable re-entry vehicle (MaRV), a program for increased missile accuracy. Meanwhile the Soviet missile program has also made great progress, with MIRV being tested, apparently successfully, on three different new missile systems.

After the partial test ban treaty, and again after SALT I, it was necessary to assuage domestic critics of these treaty agreements by promising a vigorous research and development program. Indeed, the partial test ban apparently resulted in very little limitation on weapons progress, as both the United States and the Soviet Union pursued increasingly elaborate and sophisticated underground testing. The SALT agreement was used in part to justify new weapons programs in this country, while the vigor of the Soviet missile test program suggests that this may have been the price paid for the agreements by the Soviet leadership to its military critics within the Soviet Union. There are indications that both sides intended to utilize some of the resources that would be saved by the agreements not to deploy ABM in order to accelerate research on new offensive systems. These could then be substituted for existing systems within the quantitative limits set by SALT. In fact SALT, by permitting the substitution of qualitatively improved weapons for older ones, provided a powerful incentive for weapons-system innovations on both sides.

The testing or demonstration of new technological weapons can be politically as destabilizing as their actual deployment, especially in the absence of reliable intelligence. Thus the projected bomber gap of the mid-nineteen-fifties and the alleged missile gap of the early sixties were inferred from Soviet capabilities that had only been demonstrated on the level of research and development or prototype testing. The inferences proved unfounded, since there was no major deployment of either bombers or ICBMs. But the United States had in the meanwhile launched a major build-up of bombers and ICBMs, which gradually acquired a justification of its own, independent of the hypothesized but non-existent threat that had originally inspired it. Similarly the mere possibility that the Soviets were about to demonstrate an ABM capability around Moscow was used to justify the vigorous pursuit of a MIRV program in the United States and ultimately the deployment of MIRVs on both the sea-based and the land-based forces.

Until recently, official scientific advisers and some of the scientific community interested in such matters have advocated research and development to improve certain weapons technologies, even when they have strongly opposed the deployment of the corresponding specific weapons, whether because they were ineffective or because they would accelerate the arms race. Over a period of nearly fifteen years, independent scientific advice discouraged deployment of successive ABM systems. But each time the independent scientists recommended against deployment, they also advocated more research aimed at the next level of improvement, primarily on the grounds that we could not afford to be taken by surprise over what was technically possible. Thus Nike Zeus was abandoned in favor of the development of Sentinel and, subsequently, of Safeguard. Next, the limited deployment of Safeguard was accompanied by advocacy of a strong research and development program for Hardsite, which turned out to be a system designed to meet the arguments of those who had publicly opposed the deployment of Safeguard. Only the ABM treaty brought about the abandonment of this program.

Since SALT, however, one hears less talk of the pursuit of "R and D" as an alternative to deployment. The possibility of limiting technological progress in weapons *prior* to a deployment decision is beginning to be seriously discussed by those interested in arms control.

This essay will be concerned with the impact of qualitative progress in weapons technology and with some possible means of controlling it. We will first deal with the impact of technology on the stability of the strategic deterrent and with the potential political effects of qualitative progress in conventional weapons. We will then consider several types of proposals that have been made for slowing the rate of technological progress in weapons development, with emphasis on strategic weapons. The final section will discuss the overall system of weapons development and procurement and will analyze those parts of the system that appear to generate pressures and incentives to perpetuate it.

I. Prospects and Impact of the Qualitative Arms Race

How do qualitative changes in weapons affect the world military balance, and what does "stability" mean in the military situation? Clearly any change that increases the advantage of the side attacking first contributes to instability, and any change that reduces this relative advantage is stabilizing. This is true at both the "strategic" and "tactical" levels. Thus the development of invulnerable retaliatory systems, such as Polaris, has contributed to stability because these systems guarantee the destruction of the side that attacks first; the first attack would scarcely attenuate the completeness of the retaliatory strike. An increase in the relative effectiveness of antitank weapons would also tend to reduce the incentives for a first strike in land warfare. Improved strategic intelligence, that is, instant knowledge of the opponent's deployments, is also generally stabilizing, especially if the intelligence capability of each side is fully known to the opponent. The ABM, on the other hand, was considered destabilizing because it presented the possibility of limiting the damage from a retaliatory strike. MIRV was also considered destabilizing because it potentially limited the effectiveness of a land-based ICBM system deployed in a retaliatory mode. Forward-based nuclear weapons in Europe are destabilizing to the extent that they might be immobilized by surprise attack, especially a conventional one. Finally, conventional weapons whose effectiveness in an initial attack can be greatly enhanced by time for mobilization are destabilizing because they provide an incentive for the opponent to counterattack before mobilization can be effected; the classic example of this can be found in the outbreak of World War I.

Stability is a political as well as a military concept. It is in its political aspect that technological innovation is particularly important because of the long time lapse between a demonstrated capability and full deployment of the corresponding weapons system. Thus any technological achievement that becomes known to the other side and that, when fully deployed, would jeopardize the effectiveness of retaliation (whether at the strategic or tactical level) is bound to create apprehension about the future and stimulate counteraction. The result is a spiral of technological innovations. The principle of overreaction or "worst case analysis" generally guarantees that the reaction to a revelation of technological innovation in weapons exceeds what was justified by the actual situation.

Technology and Military Equilibrium

In the past twenty years, technological change has sometimes increased and sometimes decreased the stability of the strategic deterrent. For example, the first liquid-fueled ICBMs contributed to instability because they were not "hardened" and could not be made instantly ready to fire. This would have provided an incentive for the other side to launch its weapons first, in order to destroy the vulnerable weapons before they were functional. On the other hand, the development of solid fueled ICBMs, and especially of submarine-launched ballistic missiles, resulted in a less vulnerable retaliatory capability; this reduced or eliminated the incentive for pre-emptive strike and thus improved strategic stability. Similarly, the development of satellite surveillance decreased the likelihood that either side could deploy strategic weapons secretly. Satellites with infrared detection insured immediate warning of a missile attack launched from anywhere in the world, which reduced the likelihood of successful pre-emptive attack. It also decreased the instability that results from exaggeration of enemy capabilities or a misinterpretation of enemy intentions stemming from unreliable intelligence.

When the ABM emerged as a technical possibility in the nineteen-sixties, its technological threat to strategic stability was immediately recognized because it cast doubt on the effectiveness of a retaliatory strike. In principle, the development of MIRV similarly threatens stability, as the ratio of the number of independently targetable re-entry vehicles to the number of missile launchers increases the likelihood of success of a pre-emptive strike against the enemy's land-based launchers. The prospect of anti-submarine-detection technology, which could make impossible the concealment of sea-based missile forces, would also be a potentially destabilizing development.

If neither the ABM nor MIRV had been developed, the strategic situation at the end of the nineteen-sixties would probably have been at its most stable. Both sides possessed land-based and sea-based missiles, which were virtually certain to survive any initial attack with undiminished effectiveness, while the cities and industrial capacity of each superpower were defenseless against retaliatory strikes. A basic objective of the SALT negotiations would then have been to freeze—or at least prolong—this balance. The ABM treaty contributed greatly toward this end, but the other developments mentioned earlier worked against it. What now are the prospects for the future?

It is first fair to ask whether we can expect the development of a qualitative arms race to be as rapid today as it was from 1955 to 1965. The revolutionary technological situation that existed then may have been unique. Since the perfection of MIRV, most of the military technologies that have been proposed are only evolutionary refinements of basic systems concepts developed and implemented earlier. The Trident submarine and missile system is simply a parameter extension of Polaris. The B-1 bomber is an embodiment of previous developments in supersonic fighter and reconnaissance aircraft. Recently proposed versions of the ABM were extrapolations from the basic elements of the Nike-X system, which were incorporated first in Sentinel and then in Safeguard. Prospective improvements in missile accuracy are logical evolutions of technological trends that have been evident for a long time.

The revolutionary fifties and sixties were made possible by the confluence of several basic technological advances which came to maturity at more or less the same time—solid-fuel rocket propulsion, high yield-to-weight thermonuclear warheads, inertial guidance, compact solid-state electronics and computers, MIRV and re-entry technology. With the possible exception of the application of laser techniques in missile defense and ground warfare, comparable technological developments are not now on the horizon that promise the sort of qualitative leaps we witnessed then. We ought, however, to remind ourselves that the rapid advances from 1950 to 1960 were not anticipated until they were almost upon us, even though they may appear in retrospect to have been foreseeable. Scientists and technologists, in trying to foresee the state of the art more than five years into the future, have been notoriously myopic—conservative as to actual possibilities and inaccurate in their anticipation of the direction of development. Thus, it would be injudicious to hope that the posture of mutual assured destruction is proof against technological change for more than five, or at most ten, years, We cannot reliably see that far into the future, given past rates of technological progress in military weapons systems.

In addition, the cumulative effect of many small evolutionary improvements in the parameters of component technologies can often be as revolutionary as such dramatic, basic developments as the transistor or the hydrogen bomb. There are at the moment several technological areas where such a cumulative evolution might occur. One is in the accuracy, reliability, and compactness of guidance and control, including terminal guidance or "homing" of multiple warheads. One cannot foresee any natural technical limits to improvement, especially as electronic techniques gradually replace mechanical methods.[1] Closely related are prospective gains in the sensitivity and discriminatory power of remote sensing methods, using refined sensors and such information-processing techniques as pattern recognition.

The storage, processing, and manipulation of information are areas still undergoing rapid advance. The cost per logical operation, or per unit of information storage, has not reached any obvious lower limits, and it is likely to continue to decrease by a factor of two or three every five years, at least to the end of the century. The same will apply to the space required for information storage. At the same time, global communications via satellite permit the assembly of many different items of information into a single integrated system.[2]

These developments have only begun to reveal their potential, and they have as yet unclear implications for all kinds of weapons systems, ranging from battlefield weapons to warheads for MIRVed ICBMs, and including automatic map-following cruise missiles and unmanned bombers. In principle, increasing accuracy and discrimination should make it possible to decrease the collateral destructiveness of warfare and to confine damage to military objectives, and this may increase the temptation to initiate military action under less provocative circumstances than at present. Accuracy might also be increased to the point where conventional explosives could be substituted for nuclear weapons, thus making possible military actions which, under present circumstances, would require crossing the nuclear threshold. Increased accuracy might also raise the temptation to deploy very low-yield nuclear weapons, especially in Europe, and might thereby erode the "fire break" between conventional and nuclear tactical warfare. It is, of course, difficult to generalize about the effects of such technological improvements on the likelihood of hostilities or of escalation; it would depend upon a specific situation.

The use of "smart bombs" in Vietnam provides the first case history for this type of development. However, according to R. L. Garwin, the bombs were used in such limited quantities that it is difficult to draw any conclusions regarding their effect on collateral damage. As yet there is no indication of modification in the long-range trend toward increased collateral destruction by high explosives in conventional war. If one plots the rate of delivery of high explosives as a function of time in the wars this country has waged in the twentieth century, one finds that this rate has doubled every eight to ten years. This increase in accuracy and discriminatory power has, however, been more than offset by technological developments that have increased the feasible rate of delivery of high explosives, and, consequently, the amount of non-military damage has continued to escalate, as evidenced by the destruction in Vietnam.

The combat manpower needed to deliver a given amount of destruction within a given time has also constantly declined over the years, although the value of this manpower measured by the time and cost of training has increased. In other words, conventional war has become increasingly capital intensive. In consequence, it has become possible to inflict more and more damage with less and less risk to the lives of combat personnel—and hence minimal political cost at home. It was in this way that improvements in technology made it possible for the United States to escalate the civilian destruction in Indo-China while "de-escalating" the intensity of combat from the perspective of domestic politics. If the laser-guided bomb, or another comparable sophisticated weapon, had been available sooner, it is possible that the war could have been carried on with even less internal political opposition than it finally generated. As technology facilitates ever more sophisticated automated violence, the possibility of clandestine intervention in local conflicts by the superpowers, with minimal internal and external political cost, may increase. This could become a growing source of instability.

It seems only a matter of time before increases in the accuracy with which re-entry vehicles can be aimed or guided will make fixed land-based missiles vulnerable to attack. Whether such attack would actually be a serious threat would depend upon the vulnerability of the other components of the potential retaliatory force, especially the sea-based deterrent discussed below. Even if a first strike against the land-based missile force were not credible, the justification for a fixed land-based force as part of the deterrent would decline. In fact, the mere presence of potentially vulnerable land-based missiles would tend to present "hawks" on each side of the Iron Curtain with arguments for building up the strategic-weapons inventory. The missiles would become a target to be defended just because they were there, even though they made no contribution to overall retaliatory capability. In this sense, they would be an "attractive nuisance," tending to draw enemy attack for precautionary or symbolic reasons. To this degree, improvements in re-entry vehicle accuracy will contribute to strategic instability, psychologically if not in fact.

Another question is whether submarine-based missiles can eventually achieve sufficient aiming precision to pose a credible first-strike threat against the other side's land-based missiles, or against other military targets. There is no fundamental technical obstacle to this, although the military advantage of such a development would be dubious so long as each side retained an invulnerable retaliatory capability.

Invulnerability of the Sea-Based Deterrent

Perhaps the most serious question for the stability of mutual deterrence is whether any technical changes are in prospect that might compromise the invulnerability of the submarine missile forces of either side, and thus undermine the certainty of retaliation. An anti-submarine-warfare (ASW) system that could compromise the deterrent effect of the submarine-based missile force would have to meet very stringent requirements. It would have to be able to make a surprise pre-emptive attack simultaneously on all the enemy's submarine missile forces, including those in port. Such an attack would have to be made with close to one hundred per cent confidence, for if even one submarine escaped destruction it would have the capacity for inflicting serious and probably unacceptable retaliatory damage on cities and population. Furthermore, any action against the submarine force short of pre-emptive attack would provide strategic warning and hence would risk drawing some form of counterattack.

A war of attrition against the sea-based deterrent would be technically somewhat more feasible and could be imagined as a form of political backmail. Unless the nation attacked were in a position to retaliate without at the same time destroying itself, this form of political blackmail is risky, but barely credible. In practice, however, there are too many options for a less drastic response, including a retaliatory campaign of attrition against the enemy's sea-based forces. Nevertheless, belief that an opponent had the capability of conducting such a war of attrition could contribute greatly to tensions and produce political instability. Thus the demonstration of certain qualitative capabilities in ASW, without any evidence of deployment, might provide incentives to accelerate the arms race, much as the mere hint of a possible Soviet ABM system contributed to the deployment of MIRV.

Returning to the question of pre-emptive attack, the difficulties seem almost insurmountable. It would require detection, positive identification, and close and continuous tracking of all missile-firing submarines, plus the ability simultaneously to launch a lethal ASW weapon at each submarine on command from a central point. The requisite assured destruction could probably be achieved only with nuclear underwater weapons fired from vehicles that could carry sonar tracking gear close to the target, while remaining relatively immune to the effects of nearby underwater nuclear explosions. Hydrofoils, hovercraft, helicopters, or similar exotic vehicles might be made to have these characteristics. However, the tactics for such an operation could not be developed without a great deal of rehearsal and training, probably including the fairly routine practice tracking of potential targets. Such exercises could hardly be ignored by an alert opponent.

One could also imagine the disposition of passive and active sonars over the oceans, which could be monitored by satellite and would assist tracking operations, but the necessary dispositions would be very costly and would have to be in place continuously and be highly reliable. As sophisticated signal-processing electronics and information storage become more compact and inexpensive, world-wide monitoring of submarines, closely coordinated with trailing vessels, becomes conceivable, though still very costly. For this reason, there are arms-control incentives for trying to inhibit such developments, whose mere demonstration would stimulate doubts about the future invulnerability of the deterrent. The nation under threat could also develop decoy vehicles to confuse both the trailing vessels and any ocean-wide surveillance system designed to assist them. The same electronic sophistication that facilitated ocean surveillance would make possible relatively inexpensive decoys against tracking techniques that could simulate the characteristics of submarines. Even a small number of sufficiently realistic decoys could confuse the would-be attacker and greatly increase his uncertainty as to whether some part of the retaliatory force might have survived his attack.

A careful consideration of possible technical threats to the sea-based deterrent therefore forces the conclusion that they do not reveal a clear-cut technical advantage either to ASW or to the survival of the deterrent. The launching of a major ASW program would most likely simply trigger a race between measure and countermeasure, ending in an expensive stalemate similar to that which probably would have resulted from an ABM versus land-based missile race.

Conclusion

In the foreseeable future, the qualitative arms race is not likely to lead to major strategic instabilities, provided the ABM treaty remains in force. Nevertheless, continued innovation could lead to wasteful and expensive deployments of weapons, and it could offer many opportunities for internal bureaucratic maneuver aimed at exaggerating technological breakthroughs in order to justify new programs. One counter to this is certainly more open discussion and criticism of weapons proposals in a wider arena of opinion. By carefully considering the reaction to, and possible countermeasures for, the next generation of systems, such discussion would have the effect of deflating the benefits claimed for the development and deployment of proposed new systems.

II. Potentials for Curbing the Qualitative Arms Race

In the past it has often been assumed that limitation of progress in weapons technology was rendered impossible by the difficulties inherent in verifying such limitations, especially in the research and development stage. Thus, arms-control discussions have tended to concentrate on agreements for numerical limitations to the deployment of certain classes of weapons that can be verified with reasonable confidence through unilateral intelligence means. However, even the Partial Test Ban (PTB) was an attempt to limit technological progress in the sense that it was expected, through the prohibition of atmospheric tests, to inhibit the development of high-yield nuclear weapons and to make all weapons testing more costly and thus slow it up. In fact, the PTB did not prove to be as inhibiting as expected. Its main benefit was the reduction of atmospheric contamination. But driving tests underground made them publicly less visible, and thus reduced the pressure of world opinion for further damping the qualitative race in nuclear arms.

The SALT agreements did include a specific prohibition of the testing of certain kinds of ABM components of satellite-based ABM development. Less than complete confidence in verification was accepted in these agreements, which seem to have set a precedent for other possible limitations without insistence on verification. That verification is as much a political as a technical matter, that perfect verification is impossible, and that it is also unnecessary if there is some measure of political trust are also increasingly accepted ideas. The terms of an arms-control agreement are sufficiently interconnected to allow each element to affect the others, and hence not every element has to be verifiable with complete confidence so long as some parts of the agreement can be tested on a sample basis.

Obviously, the closer a weapons system is to deployment the more readily can its progress be verified. The final proof-testing of a weapon, necessary to demonstrate sufficient confidence in its reliability to warrant deployment, is a large, complex process, and it is difficult to conceal. On the other hand, once a weapon has reached that stage, bureaucratic vested interests have usually consolidated to insure its further development, so that ease of verification is offset by greater internal bureaucratic momentum. In what follows, we shall examine a series of proposals, starting with those that aim at inhibiting innovation nearest to the final deployment stage and ending with attempts to limit innovation at earlier stages of the process. The object of all these proposals is to prohibit or retard developments that are politically or militarily destabilizing or that simply add to the costs of maintaining a military posture on both sides without contributing to the security of either.

Comprehensive Nuclear Test Ban (CTB)

The prohibition of all nuclear testing has been an important aim for arms control from the very beginning. Its importance derives from the belief that no nation will place a new type of weapon in inventory if its properties cannot be realistically tested or its reliability verified by proof testing. It is theoretically possible to develop and deploy a nuclear weapon on the basis of scaled laboratory tests alone, but confidence in the reliability and the characteristics of such a weapon would probably be too low for use in a crisis.

The past obstacles to conversion of the limited test ban treaty of 1963 into a permanent comprehensive test ban (CTB) have been American insistence on the need for on-site inspection for suspected underground nuclear tests and the alleged value of underground nuclear explosions for peaceful purposes, such as large earth works or the stimulation of natural gas sources. On the Soviet side, a desire not to subject itself to limitations not enforceable against the Chinese was probably also an important factor. More generally, neither side was prepared to accept constraints that would decisively impair its subsequent freedom of action. The PTB was acceptable precisely because it contained no real constraint on innovation in nuclear weapons or peaceful uses.

Since 1963, the technology of detection and identification of underground tests by unilateral means has advanced rapidly, more rapidly than most scientists then expected it could. It is now doubtful that significant weapons advances can be made using tests that are small enough to escape detection with certainty. Even if progress could be made with such small tests, reliable warheads would probably not be placed in inventory without conducting many proof and training tests, a few of which are likely to be detected and to provoke suspicions. The non-adherence of other powers to a CTB could be handled by an agreement of finite duration, subject to reopening if a universal ban were not achieved within a specified period of time. Such an interim agreement would probably increase the pressure on all nations to adhere formally to the ban. Unlike the situation in the non-proliferation treaty, the superpowers would be taking the lead in foregoing their freedom of action, as opposed to demanding a forebearance from others that they were unwilling to impose upon themselves.

There is, perhaps, a risk that significant new results achieved in the laboratory would become dammed up, as it were, behind the test ban, and that one power might then denounce the ban and launch an accelerated "testing race" to verify its laboratory findings, thus creating political tensions that might not otherwise have occurred. Such a risk seems worth taking in view of the political benefits of a CTB.

New weapons that might be developed clandestinely under a CTB would principally be very small pin-point battlefield nuclear types. Indeed, with sufficient improvement in accuracy, such "mininukes" could be used in conjunction with MIRV to threaten land-based missiles and other military targets, with very little collateral civilian damage. On the battlefield, the use of such weapons would tend to blur the threshold between conventional and nuclear war and thus reduce inhibitions against crossing it; this might tend to make nuclear war more likely. The threat to land-based missiles would be similarly destabilizing. On the other hand, it is doubtful that such weapons could ever be decisive in providing military advantages to the side that developed them. Their destabilizing effects would outweigh any contribution they might make in terms of military advantage. Hence one could argue that, to the extent that a CTB made the development of such weapons more difficult and risky, it would be advantageous to world security, while, to the extent that it did not preclude such development, the security of one side or the other would not be seriously jeopardized. In sum, the possibility of the development of "mininukes" provides an additional argument in favor of a CTB.

Limitation on the Number of Missile Launchings

Experimental launchings are an essential part of missile development and are at the same time readily detectable by unilateral methods, using observation from satellites as well as electronic monitoring of communications and telemetering. In addition, training and confidence missile firings are necessary to keep a weapons inventory in readiness. Therefore, limitation of the number of test firings is a potential means for retarding innovations in missiles that can be verified unilaterally. The limitation that would be most practical to enforce would be one on the total annual number of firings, whether for research and development, proof testing, or training. The difficulty is that the number of launchings permitted would have to be sufficient to allow each side to retain confidence in the readiness of its deterrent, but that this number, if entirely diverted to research purposes, might permit one side to achieve a dangerous technological advantage. Separate limits on confidence firings and on research and development launches would be a preferable alternative, but they would be much harder to enforce because of the difficulties involved in distinguishing experimental from proof launches. For this reason, a limitation on total number of launches, combined either with agreements or with mutual declarations foregoing specific kinds of research, development, testing, and evaluation, would be more practicable.

Restrictions to Permit International Observation on the Location of Target Areas

As pointed out by Herbert York,[3] the SALT agreements included a provision for restricting ABM tests to specified test ranges. This stipulation suggests an excellent precedent for a restriction on all kinds of missile testing to specified ranges and for a restriction on down-range impact areas to locations that can be fairly easily observed by other countries, for example, international waters, or land sites close to international boundaries, or coastlines. Such mutually agreed-upon restrictions would improve ability to distinguish between experimental and proof tests, and they might thus make separate limits on the number of such tests more feasible. Furthermore, the SALT agreements have established a precedent for prohibiting interference with unilateral means of observation, either directly or through attempted concealment of certain classes of activities, such as construction of missile silos. The reaffirmation of this concept in the case of missile testing would clearly be desirable.

Specific Prohibition of Potentially Destabilizing Missile Improvements

When York[4] suggested restricting the location of the target areas, in 1972, he had in mind the testing of such improvements as maneuvering re-entry vehicles, re-entry vehicles with greater "fineness ratio" (i.e., that could be aimed at more widely separated targets), and tests involving complete MIRV systems. Unilateral observation methods, combined with the restrictions outlined above, would have made the probability of detection of tests involving any of these improvements great enough not to warrant the risk of being caught in a violation. Unfortunately, most of the technological deployments these proposals were designed to prevent have now already occurred.

Even at the present stage in the evolution of MIRV, however, the prohibition of testing of complete missile systems could still prevent obtaining confidence in the reliability of MIRV sufficient for use in pre-emptive attack. Indeed the dismal record of the Poseidon missile[5] is illustrative of the pitfalls along the path from the drafting board to a weapons system of fully demonstrated reliability.

Any agreement to forego specific weapons improvements, even if not strictly enforceable or verifiable, would still provide a strong argument for opponents of these developments in the internal bureaucratic debates within a country. It would be difficult to conceal illegal developments that could gradually become known to large numbers of people. Even a simple mutual declaration could strengthen internal opposition. On the other hand, it could equally be argued that illegal weapons developments could be more easily concealed in the compartmentalized research systems of the closed societies, and this would tend to limit the extent to which unverifiable agreements on innovations could safely be undertaken by the United States.

Another danger is that ambiguous results from unilateral observation could be misinterpreted as evidence of prohibited activities when none existed and could create political tensions unnecessarily, or at least put a potent argument in the hands of the internal opponents of agreements. This is an objection that still has to be answered; but the Standing Consultative Commission created by the 1972 SALT agreements might prove a useful mechanism for insuring against such misinterpretations.

Improved missile accuracy is also a potentially destabilizing development which has recently been the subject of a great deal of discussion in the United States. While it would no doubt be desirable to inhibit such improvements, it is very hard to see how this could be done and still maintain confidence on either side that the prohibition is being observed. Improved accuracy is extremely difficult to verify in the observation of proof testing. On the other hand, given the size of present strategic forces, accuracy has no military value so long as the posture on both sides is truly confined to mutual assured destruction. The problem arises when more limited "counterforce" options are included into the overall deterrent posture. The United States is already ahead in this respect, and little would be lost by even an unverifiable agreement to forego further development in such technology.

In principle, mutual recognition of the impact of technological developments on the stability of deterrence might have considerable political value, even in the absence of verifiable restrictions. The major powers could declare their intent not to develop weapons threatening the survivability of the other side's invulnerable retaliatory capability. Such a public declaration by the United States and the Soviet Union could have the salutary effect of forcing communication within each government about every new weapons system and even some of the old ones. It would legitimize, at a very early stage, internal concern about the destabilizing effects of various potential weapons developments. Declarations of this sort would be no different in principle from the declaration of intent in the 1972 Moscow agreements to forego both interference with the unilateral intelligence means of the other side and concealment of strategic weapons. Such a declaration might become the basis, within this country at least, for requiring an "impact statement" for each new major weapons development, analyzing the impact of the proposed system on actual and perceived strategic stability and on international political stability generally.

Restrictions on ASW Research and Development

As we have already seen, strategic stability is especially sensitive to technological developments that tend to compromise the invulnerability of a sea-based deterrent. This suggests that possible limitations on ASW developments are of special importance in any attempt to inhibit the qualitative arms race. Unfortunately, it is very difficult in practice to distinguish between techniques that threaten the submarine deterrent and those directed at protecting sea communications generally from submarine attackers. In this respect there is a geographic imbalance between China and the Soviet Union, on the one hand, and the Western industrialized nations, on the other. The latter, including Japan, are much more dependent on sea communications, both economically and militarily. The maritime nations will, therefore, be unlikely to forego the development of any ASW technique that would offer protection against submarine attack on commercial shipping or naval forces. Even an ocean-wide surveillance system, designed primarily to monitor and track the opponent's deterrent fleet, would offer considerable incidental protection against submarines deployed to raid shipping. Since the main shipping lanes cover only a small fraction of the oceans over which a deterrent fleet might range, we might try confining surveillance to those vital lanes, leaving large areas of the ocean as "sanctuaries" for missile submarines. This would work most effectively if the surveillance systems were of the "distributed" rather than the "searchlight" type. By a distributed system, we mean an interconnected array of passive or active sonic detectors distributed very widely over the oceans, but with each individual sensor capable of detecting a submarine only within a relatively short range. By a "searchlight" system, we mean a much smaller number of highly sophisticated, directional, long-range sensors capable of detecting submarines and locating them over a very extended geographical area—hundreds or even thousands of miles distant from an individual sensor. The distributed system could be deliberately confined to major shipping lanes, or "corridors," and thus would not threaten the opponent's deterrent force, so long as it avoided those corridors. The searchlight system, however, would cover large sweeps of ocean, and it would thus inevitably detect the opponent's deterrent force as well as its attack submarines threatening the shipping lanes. The problem is that future developments in technology may make searchlight systems considerably less expensive than distributed systems for a given degree of coverage. In addition, all kinds of intermediate configurations between "pure" distributed and "pure" searchlight systems are possible. In practice, it may be difficult to make distinctions between the two kinds of sensor deployment sufficiently convincing to assure an opponent that his strategic forces are invulnerable, so long as they avoid well-defined geographical areas.

Techniques for continuous trailing of submarines might also threaten deterrent forces without being especially useful for the protection of naval or commercial shipping. This is because, in a campaign against attack submarines that threaten shipping, the primary objective is to destroy the submarine immediately after it is detected and located. Since hostilities would then already have begun, there would be no reason to withhold attack once the submarine is positively identified as hostile. But continuous trailing of such submarines without attacking does not add much to the protection of sea communications, and it is, therefore, probably not worth the extra cost. The only advantage of trailing might lie in more secure identification of submarines as hostile. But, for this and other reasons, maintaining the distinction between protection of shipping and threatening the opponent's deterrent forces may be harder to maintain in practice than in theory.

Nevertheless, a declaration foregoing the effort to develop a trailing capability may have considerable political value, especially if coupled with an agreement limiting the construction of attack submarines capable of interdicting sea communications. Such a *quid pro quo* would make for greater symmetry between the "heartland" powers and the maritime nations, and it would make limitations on ASW of a more fundamental sort worthy of serious consideration.[6]

Finally, more searching questions must be raised as to how realistic, under modern conditions, concern about sea communications really is. The powerlessness of the non-Communist industrial nations in the face of the Arab oil embargo suggests that, in a world as interdependent industrially as ours, sea communications may no longer be the weakest link in maintaining war-fighting capability in a long-drawn-out conflict. At the very least, the traditional arguments for sea power and sea communications need to be carefully restudied in the light of a world economy now radically different in the extent of its interdependence from that which existed at the outbreak of World War II.

The Limitation of Military Budgets

There are two main arguments for limiting military expenditures. The first is that it is the most direct means for slowing the arms race without having to conduct endless technical bargaining over the equivalence of specific weapons systems. The second is that the resources thus saved could then be devoted to the solution of other basic international problems. Indeed, to the extent that military expenditures divert the world's resources from economic development, they become major contributors to world political instability, quite apart from the more direct effects of the "toys" on which the money is spent.

Two ways of approaching reduction of military budgets are: 1) reduction of the total military budget by mutual agreement of the superpowers (with the intention also of constricting military research and development); or 2) direct reduction of military research and development budgets only. Either of these methods presents problems because a great deal of military-related research is supported from outside the formal military budget. In this country, the AEC and NASA budgets include a large military component, and some military research and development is probably hidden in other appropriations (*vide* recently highly publicized technological expenditures of the C.I.A.). Early exploratory research is especially easy to bootleg under other categories of expenditure. In the Soviet Union a great deal of military research is apparently part of the "science budget," and it is not included in reports of military expenditure.

Another difficulty is that what we call "test and evaluation" and what the Russians call "assimilation into production" are excluded from research and development in the Soviet system, though included as such in American expenditures. On the other hand, a considerable amount of "independent R. and D." by industry in this country is not treated as military, although it is indirectly financed out of military procurement appropriations. There are also important differences in the cost factors for military research and procurement between the United States and the Soviet Union, so that direct comparison of any military budget is exceedingly difficult. Although salaries of technical personnel are lower in the Soviet Union, the rate of "productivity" in technical work is almost certainly much lower as well. For example, the Russians lack a high quality instrument industry, with the result that much experimental equipment is made and maintained by individual scientists.

Nevertheless, even recognizing these difficulties, the possibilities of mutually agreed limitations in military budgets should not be dismissed completely, especially if they could be coupled with agreements to deploy the skilled manpower thus released for some more beneficial purpose, such as the development of new energy resources related to world development.

Demobilization of Manpower and Facilities Devoted to Military Research and Development

York[7] has proposed a plan for the gradual removal of secrecy from research, so that scientific findings may ultimately be redirected to other purposes, and he cites the conversion of the Fort Detrick biological-warfare facility to cancer and related biological research as a precedent for what might be achieved on a larger scale in other areas of military-related technology. He proposes the annual transfer of five to ten per cent of the people now working on secret projects to "non-secret projects conducted in open facilities." Since this would result in a much more rapid increase in non-secret publishable research than could be accomplished through the normal growth of the scientific community, the transfers could be readily monitored, especially if the United States and the Soviet Union would also agree to an exchange of statistics on scientific and technical personnel, including the occupations and organizational affiliations of new university graduates.

There is no question that secrecy in research has contributed greatly to the mutual suspicions and the apprehensions about "technological surprise" that have characterized so much Cold War thinking. The monitoring of the transfer proposed by York would be facilitated by the natural inclination of scientists and engineers to disseminate their work among their peers and thus gain public credit for priority in discovery or invention. It might even be possible to organize official international meetings dealing with military technology, its progress, and the assessment of its broader effects and socio-political implications. Eventually an authoritative public literature on military technology might appear, open to criticism and evaluation by the international technological community.[8]

This greater openness in military technology may not only reduce apprehensions about "technical surprise," but also make it more difficult for the "hawkish" experts in any country to use selective release of information about an opponent's technical capabilities as an argument for large new weapons programs. On the other hand, too much publicity may stimulate irresponsible "gadgeteering" and unreasonable public fears about weapons possibilities that are in fact impractical.

There are also those who would argue that secrecy encourages inefficiency and "boondoggling" with resources that might be used much more effectively if the public were really privy to what was going on. While this is certainly a possibility, we believe that the advantages of publicity and open criticism outweigh the dangers of accelerated progress in politically perilous directions.

Unilateral Action of Scientists as a World-Wide Community to Withhold Their Services from Military Research and Development

It has been argued that, were scientists simply to refuse to participate in military research, the qualitative arms race could be slowed and the "technological imperative," which drives advances in military technology, could be dampened. A frequent proposal has been for a kind of Hippocratic Oath of scientists (and presumably also engineers) not to engage knowingly in research whose purpose is to facilitate the destruction of human life or the injury of fellow human beings.[9] Another similar proposal is for a professional "codes of ethics" among scientists, which would be made prerequisite to membership in a professional society and would necessarily be combined with some licensing system. Sanctions could then be applied, after the manner of disbarment proceedings in medicine or law, which would effectively prevent individuals who violated the code from earning a living in their profession. Still other proposals have included forms of strike or boycott against organizations engaged in military research. These, however, are effective weapons only if the decision of a majority of members of an occupational group can be enforced on the entire membership. They are ineffective unless employment in a profession can be given some attribute that the entire group can benefit from collectively, or not at all.

Perhaps the most obvious point to be made in connection with all these suggestions is that, to be effective, they would have to involve sanctions against individuals that could reach across national lines. A code of ethics enforced effectively in one nation and not in another would not much inhibit military technological progress, and it could well lead to alterations in the military balance that would increase rather than decrease the likelihood of conflict. It would also be enforceable only in a world already largely disarmed, i.e., in which the overwhelming number of technical people were engaged in non-military research. At present, one quarter of all technologists derive some support for their work, if not their livelihood, from military research, and—in the absence of realistic employment alternatives for these people—the code-of-ethics idea does not appear very practical. A partial adoption of such a code would only tend to isolate military scientists from the moral climate of the majority of their fellow professionals, thus making military development less rather than more sensitive to broader human implications.

A second and perhaps more fundamental point is that the distinction between "good" and "bad" research is much more difficult to draw in practice than the simplifications required for collective action can accommodate. Except in the final stages of development, most technical progress has manifold implications. Furthermore, so long as the use of force or the threat of force is an accepted instrument of international politics or domestic security, the line between "good" and "bad" research will remain obscure. Is it evil to work on temporarily disabling chemicals when the alternative may be thoroughly lethal bullets? By what logic is tear gas a legitimate police weapon in domestic disorders, but an illegal weapon in international conflict?

If the use of conventional air-dropped bombs is a legitimate form of warfare, is research directed toward improving their ability to discriminate more accurately between military and non-military targets to be regarded as aimed at the destruction of human life or at its protection? Is research directed at improving intelligence gathering about military matters stabilizing or destabilizing? Will research on body armor for infantry and police be condemned or condoned by a "Hippocratic oath"? What is the moral status of research directed at better care of war casualties? These examples just begin to indicate the complexity of the issues. Codes of ethics usually break down when applied to such complex moral questions, as we already know from modern medical practice.

One could, of course, take the position that any research whose results are likely to be used primarily in a military setting is morally suspect because its ultimate purpose is to facilitate the killing or injuring of fellow human beings. One could even argue in favor of allowing military action to become *more* lethal for the sake of making force ultimately less acceptable as a means for settling political conflict. Such subtleties, however, do not lend themselves to the kind universal moral consensus essential to the enforcement of a professional code of ethics.

The final argument is essentially a political one. If the majority in a nation decides that a certain course of action is legitimate and desirable, does some small group have the right or duty to withhold its special skills as a means of enforcing its own political value judgments on the majority? Most of us would agree, I think, that the *individual* has the right and duty to follow the dictates of his own conscience, and that he should be afforded some protection by society in doing so. However, in an organization where the views of a majority are enforced on all members and in a situation where membership is a precondition for practicing one's profession, the problem becomes more complicated. For then one is opening up the possibility that national policy will be determined not by a majority of citizens, but by, for example, a majority of physicists or electrical engineers. Is this compatible with a democratic polity?

So long as war and preparation for the possibility of war are generally regarded as legitimate, if regrettable, national activities, it is difficult to see how collective unilateral action on the part of selected occupational groups can be either effective or politically legitimate. However, an entirely different situation would obtain with respect to activities that had been outlawed by mutual agreement of governments. Once agreements have been reached to prohibit or limit certain kinds of research, collective actions of scientists or engineers can become a legitimate and useful tool in enforcing their observation by organizations. Under such circumstances, it might even be legitimate for the majority in a professional group to enforce its views on a minority, if the action thus enforced prevents, for example, the violation of a treaty.

Reorganizing Research and Development to Minimize the "Technological Imperative"

It is frequently argued that the organization of military research in the United States creates irresistible pressures to get the resulting hardware into production, often without adequate public debate as to its full implications. (There are indications that similar kinds of pressures exist in the Soviet Union.) For one thing, the Congress is often reluctant to appropriate research funds without specific plans for a weapons system, thus precluding research to generate options from which to select. Too often development is treated as part of a rational process in which the final result should be fully defined in advance.[10] Research in industry is also funded with the strong expectation that the results will be converted into an operational weapons system. Furthermore, in a period when force levels are relatively stable, service technical organizations and their industrial clients can guarantee their own survival only by generating a continual stream of qualitative improvements to make existing deployments obsolete. This tends to be the case even though, in fact, the majority of systems undergo some development, but never reach operational deployment. The system also tends to favor "product differentiation" for its own sake, much as in other sectors of the industrial economy. Research and development that do not lead to a deployed system are looked upon as failures and a waste of resources; little value is attached in practice to the knowledge gained in a project, if there are no tangible results.

This process is driven by a "military requirements" system that is partly based on fiction. Experience has taught the military technical community that it is much easier to sell interesting research if it can be pushed as a fully conceptualized weapons system meeting a well-defined military requirement based on a well-established threat from a postulated opponent. In practice, both the threat and the requirement may have been invented to provide a rationale for a development program started for other reasons, such as to perpetuate existing organizations, or to exploit a "sweet" technical concept.

For example, in the successive ABM systems, one is struck by the persistence of the hardware and the rapidity with which the rationale for it has shifted. The purpose was originally city defense against Russian attack, became area defense against Chinese attack or accidental launching, and finally was explained as defense of missile silos and command and control centers. In addition, the members of Congress often concentrated their attention on the technical aspects of the system and on its feasibility and cost—which they were poorly qualified to judge—rather than on its political and diplomatic implications, which they theoretically were well qualified to judge. The opponents of ABM tried to find witnesses willing to testify that it would not work technically, rather than to criticize it from the point of view of national policy. Many of the technical witnesses, on both sides, were really motivated by strategic policy considerations, or their personal evaluations of the international situation, or the supposed intentions of the Soviets, but their political allies found it more politic for them to couch their arguments in narrow technical terms, partly because technical experts are often automatically regarded as having nothing useful to say on policy matters. Furthermore, technical testimony appears more "objective" and politically neutral, and it is thus thought to carry more weight with those politicians who have not yet made up their minds.

A system that has passed successfully through the advanced development stage is seldom canceled, at least overtly, through reconsideration of an established military requirement; it would be too great an admission of failure on the highest policy level. Therefore, the justification for cancellation or redirection of a large weapons system must appear to be made on technical or economic grounds. This does not mean that the history of military development is not strewn with the skeletons of canceled systems—one has only to recall the nuclear-powered aircraft, the Navaho missile, Skybolt, Dynosoar, the B-70 bomber, the manned orbiting laboratory (MOL), and literally hundreds of other smaller projects. But the tragedy is that they were canceled for reasons that in most instances could have been foreseen when the original requirements were established, although the cancellation may have been publicly justified on other grounds. Still others were carried to the hardware stage, not because they were needed but simply because there was no valid cost overrun or technical justification for canceling them.

These situations obviously constitute at least one point of convergence in interest between the advocates of arms control and the advocates of a more economical and cost-effective defense procurement system. The present system is weak because it is insufficiently responsive to policy and strategic considerations at an early stage of a systems development. Military requirements tend to become after-the-fact rationalizations of technical ideas cooked up at a relatively low level in the military-technical-contractor bureaucracy. Even the closely reasoned annual defense-posture statements may involve more rationalizations of existing development programs than appear from their format and organization. The kinds of arguments made by the President's Blue Ribbon Defense Panel,[11] though developed primarily to favor vigorous new weapons development, can be equally applied to arms control and to constraint in new weapons development. In both cases, the argument is for opening the crucial decisions to a broader range of policy considerations and to criticism by a larger public than is now the case.

Military research also leads to premature and useless development of many components of a system. In the nuclear aircraft program, for example, a great deal of effort went into development and acquisition of non-nuclear and rather conventional hardware before sufficient research had been done to determine the feasibility of making a nuclear fuel element that would meet the original performance specifications. Many of these components had to be scrapped as the system specifications were progressively adjusted downward to meet the reduced capabilities of the feasible fuel element. The histories of TFX, the C-5, and several other celebrated military white elephants provide similar examples. Yet development even of these less critical components created pressure to go forward with the entire system, even in the face of other technical failures or a reconsideration of policy.

In the late fifties, many argued against the wastefulness of the military requirements system. Such scholars as Burton Klein and Fred Scherer proposed that a much larger fraction of research and development should be devoted to improving the quality and performance of such basic items as radars, jet engines, rocket-case materials, and guidance computers,[12] without reference to a particular military requirement or systems goal. After the decision to proceed with full development, one could then choose the best "building blocks" available, without having to develop each under forced draft to meet the specifications of a full weapons system.

Criticism of defense procurement tends to focus on the "military-industrial complex" and its dynamic role in generating "planned obsolescence" in weapons systems. Without question, the symbiosis between the technical bureaucracies in the Pentagon, contractor-technical personnel, and the Armed Services committees of the Congress (usually from districts heavily benefited by defense procurement) has been a factor in the continuing preference for new weapons. However, it is not so clear that the problem could be avoided by returning to the government arsenal system, or to the treatment of the defense industry as a regulated monopoly, as has sometimes been proposed. Recent attempts to shut down obsolete military bases suggest that it is considerably harder to close a purely governmental operation than it is to cancel a large contract with a private firm, even when equally large local labor forces are involved. Ownership or control of the military-industrial complex does not in itself appear to be a crucial factor in making military development more responsive to broader policy guidance or to arms-control considerations.

Conclusion

To summarize, the most promising lines of action for controlling the qualitative arms race probably lie in mutually agreed limitations on testing, including limits on the number of permissible missile launches, and on a comprehensive nuclear-test ban. Agreements to refrain from research are often difficult to monitor, though they may have considerable value if accompanied by well-publicized commitments to refrain from actions that would jeopardize the stability of mutual deterrence. In fact, such general declarations may be more useful than attempts to negotiate highly detailed prohibitions, since they can shift the balance of the internal bureaucratic debate on whether to go forward with a given weapons development. The ban in the ABM treaty on the testing of exotic ABM techniques in space provided a precedent, though it fell short of clearly limiting research and development. Attempts at unilateral action by professional groups, such as "codes of ethics" forbidding participation in research aimed at injury to or destruction of human life, are likely to be ineffective because of the ambiguity and lack of consensus regarding what constitutes "good" and "bad" research. However, professional self-discipline that is legitimized by official mutual weapons-control declarations provides some hope.

Changes in the management of weapons-systems development, with clear stages that allow for careful analysis of technical alternatives and of political and arms-control implications along the line, promise not only greater national security for our investment, but also a less frenetic atmosphere of technological competition between the superpowers. There appears to be a convergence of interests here between the advocates of more efficient military expenditure and advocates of arms control.

III. Cutting Back on Military Research: Opportunities and Problems

In 1970, the total research funds in the world devoted to military efforts were estimated at twenty-five billion dollars, about forty per cent of the world total for research generally. Some twenty-five per cent of the world's scientific and technical manpower was engaged in research which, however general its potential application, had been originally justified primarily on military grounds. This twenty-five per cent probably represents the most sophisticated and highly trained segment of the technical community.[18] The military devotes much more money than other economic enterprises do to research and development: it accounts for one-eighth of all world expenditures for military purposes, whereas in manufacturing industries in the United States, for example, it accounts for only about four per cent of sales. From 1958 to 1965, eighty per cent of the personnel additions to research and development occurred in just two industries, aerospace and electrical equipment, i.e., those most heavily involved in government-financed defense research. In 1968 roughly forty-three per cent of the physicists in this country with doctoral degrees were at least partially dependent on military budgets for support of their scientific effort.[14] Moreover, a significant fraction, perhaps twenty per cent, of the scientific recruitment in the nineteen-sixties was accomplished through a "brain drain" of trained people from the rest of the non-Communist world, including the less industrialized countries. These immigrants were either employed directly in the American military space effort, or, probably more frequently, replaced native Americans in less technically glamorous civilian occupations. During this period, some of the less fashionable fields of engineering attracted up to fifty per cent foreign graduate students, many of whom remained in the United States.

There is now fairly wide agreement among economists that the American concentration on space defense in the early sixties had a depressing effect on innovation in the private economy, as well as on efforts for public improvement in such areas as pollution control, public transportation, and housing. A recent study by Boretsky[15] suggests that in the Netherlands and Japan the number of scientists and engineers per equivalent dollar of GNP in civilian industries is more than two and a half times larger than in the United States. This gives a somewhat exaggerated picture, because there is some civilian "fall-out" from military and space research and development in the United States, but it does suggest one reason for the recent poor performance of this country in international trade, and it is indicative of the possible price paid for preoccupation with military research over the past two decades.

To the extent that science and technology and their wide diffusion are important components of world economic development, the statistics quoted above reveal that the diversion of human resources to military expenditures is much more serious than is the diversion of economic resources. Unfortunately, this does not mean the resources can be redeployed for more constructive purposes very quickly. A recent study by Wassily Leontief and his associates,[16] using the methods of "input-output" analysis, shows that a twenty per cent cut in military expenditures in the United States, even with adjustment of aggregate demand to maintain full employment, would cause a more than thirteen per cent net reduction in research activities. This calculation is based on a 1958 input-output matrix, and there is reason to believe that the effect would be much larger if a more recent measure had been available.

While one would hope that these deficits in utilization of scientists would be transient, they do represent a serious, even if temporary, dislocation of the technical community, and they probably contribute to the political difficulties of controlling the military effort.

If one looks at the technical component of the many complex challenges facing our interdependent world in the remainder of this century, one has a sense that humanity can ill afford the diversion of talent represented by its military effort. These considerations also suggest that efforts to control military research expenditures for arms-control reasons should be accompanied by vigorous efforts to redeploy the resources thus liberated to priority civilian tasks. This may prove difficult to do, but such an effort is needed, not so much to cushion the impact of unemployment as to insure the fullest possible use of resources and capacities. These will be badly needed, especially during the last two decades of this century, when the supply of new graduates in science and engineering will be declining. It would be hoped that a significant part of the technical resources liberated from military technology could be devoted to problems related to economic development in deprived parts of the world, although this is the most difficult kind of reconversion.

The longer the world postpones addressing the problem of technological reconversion, the more difficult and intractable will it become. As military-space technology advances, it tends to become increasingly remote from potential civilian applications. In the nineteen-fifties, military aircraft became prototypes for civilian jets, and military and intelligence computers contributed to the data-processing market. But today the sophisticated equipment required for an ABM system goes far beyond what is needed for anything but the tiny scientific computing market, e.g., in numerical weather modeling. The attempt to transfer the technology of supersonic bombers and fighters to a civilian SST is proving much more expensive and of more dubious benefit than was the case with subsonic aircraft. After some early enthusiasm, it does not appear that space vehicles offer much promise for delivering the mail, or carrying intercontinental passengers, or even disposing of radio-active wastes. The booster technology required for communications satellites or earth resource survey satellites is largely of early-1960 vintage. There are still some generic technologies, such as lasers or large-scale computer memories, which have major civilian applications, but these items are mostly at the research end of the development spectrum; they do not benefit much from the large sums spent on end-item military developments. Such civilian benefit as derives from military research expenditures comes largely from the relatively inexpensive background and exploratory research that precedes systems development.

Thus, even if the American military space effort did result in useful economic "spin-off" in the past—a proposition that is increasingly being called into question—it is less likely to do so in the future. The benefits that derive from military research are greatly attenuated when classified and disseminated only within a restricted community. Studies indicate that the number of patents per dollar of research and development expenditure is much smaller for military and space efforts than for industrially sponsored research.[17] In consequence, space and military research must be justified primarily on its own merits and not on the basis of any benefits alleged for the rest of the economy. If the alternative were not to make use of the resources or skills at all, perhaps there would be some slight justification for the "spin-off" argument, but it certainly has no merit when one takes into consideration all of the other needs of society.

Some of the economic adjustments occasioned by decline in military expenditures might be handled more easily on a multinational basis. Many of the serious problems facing the world in resources, energy, environment, population, food, or economic development lend themselves to cooperative efforts among countries, and the political appeal of such cooperation would help to neutralize the negative economic effects of declining defense expenditures. The incentives for military innovation might decline if the alternative uses of technical manpower could be made more tangible through multinational action.

IV. Conclusion

Our discussion has shown that new technology has helped to fuel the arms race, though not all technological developments are potentially destabilizing to the military balance. Without doubt, a less frenetic research effort in military technology would reduce the pressures for deployment of the resulting, often unnecessary, weapons systems. It would also decrease the likelihood of still more new technological development that would give an important military or political advantage to one side, or create a situation in which safety was perceived to lie in attacking first. Any reduction in the rate of military innovation would be most valuable if it were selective, but selectivity will necessitate a system of assessment that assures consideration in a context broader than immediate political or military advantage. The notion of an "impact statement" to be required before each major decision about new weapons development might be useful, especially if it could be brought within an international or at least a multinational framework.

We have considered a number of proposals for limiting the rate of military technological innovation, with special emphasis on forestalling those that might be threatening to the stability of the military balance. Among the most useful are a comprehensive ban on nuclear testing and a limit on the number of missile tests. The political value should be stressed of mutual declarations of policy, foreswearing either development or deployment actions that would jeopardize confidence in each side's retaliatory capability. Such declarations could help to set in motion internal forces which would insure that proposed military developments are looked at more critically. The case of ASW development poses an especially difficult problem because of the ambiguity between ASW for the protection of sea communications and ASW for compromising the sea-based deterrent. However, the increasing ability of nations to cut off vital natural resources at their source without fear of military reprisal may now be fundamentally changing the role of sea communications and naval power in this equation.

Limitations on military research and development are also increasingly required to conserve technical resources for the urgent problems facing humanity. There is a growing divergence between trends in military technology and the technological needs of the rest of the world's economy. The longer the attempt is delayed to convert some military technical resources to other ends, the more difficult will this conversion become. As time goes on swords will look less and less like ploughshares.

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