# Articles

# The Decision to Modernize U.S. Intercontinental Ballistic Missiles

JOHN M. DEUTCH

**The issues surrounding the intercontinental ballistic missile (ICBM) modernization decision are addressed. Consideration is given to both Rail Garrison MX and the mobile Midgetman system. The central thesis of this article is that the flexibility and survivability of the mobile Midgetman makes this system the preferred choice for the future. A discussion of likely alternative courses of action is included—that is, doing nothing, deploying less (the current Bush Administration compromise proposal), placing Midgetman in silos, and deploying MX in multiple silos.**

SHOULD THE U.S. LAND-BASED INTERCONTINENTAL BALLISTIC missile (ICBM) force be modernized, and if so, how? This continues to be one of those eternal defense and policy questions that our political process finds progressively more difficult to answer definitively. As former Secretary of Defense Harold Brown has noted, such policy impasses undermine the nation's posture in world affairs and its influence in diplomatic negotiations with both allies and adversaries (*1*). In the spring of 1989, the U.S. Congress and the Bush Administration are once again called upon to give an answer.

My purpose is to describe the complexity surrounding the ICBM modernization question, without presuming that there is a wholly technical calculus that could or should be brought to bear in order to decide the issue. One's position on ICBM modernization depends fundamentally on judgment about basic issues—for instance, Soviet attitudes toward nuclear war under Gorbachev and after; the contribution of the prompt, hard target capability of ICBMs to deterrence; the importance of basing ICBMs in a manner that will permit them to survive a surprise attack. Reasonable individuals can and do differ about these matters and thus arrive at differing positions on the question of ICBM modernization.

In 1988, Congress and the Administration committed themselves to choose procurement and deployment of either a rail garrison–based MX missile system or a small ICBM (Midgetman) based on hard mobile launchers. In my judgment, this choice should be made in favor of the Midgetman.

## Do We Need ICBM Modernization at All?

Our paramount strategic objective is to deter nuclear war and to preserve the stability of the nuclear balance. Our deployed nuclear systems should not provide an incentive for the Soviets to strike first. The incentive is low today, and it should remain so. This means that any ICBM system deployed by the United States should be based in a manner that is survivable or that can, at reasonable cost, be made to survive any credible Soviet attack.

It has been argued, for example, by the Scowcroft Commission (*2*), that vulnerability to surprise attack should be evaluated in the context of all U.S. strategic nuclear forces: bombers, submarines, and ICBMs. This evaluation should take into account threats that could credibly develop over the *several decades* during which a new ICBM system is expected to be in operation. Thus, one must include the possibility of significant advances in antisubmarine warfare (ASW), which could make submarines that launch ballistic missiles vulnerable, or the possibility that the Soviets would deploy highly accurate sub-launched ballistic missiles close to U.S. shores so that a simultaneous attack on U.S. bomber bases and ICBMs becomes credible (*3*). Though these are not immediate threats and management by arms control is a possible path to their avoidance, who is to say what the situation will be in 20 years?

There are those who argue that an out-of-the-blue surprise attack is completely incredible and that money should not be devoted to guarding against this possibility. However, it is exactly the survivability to any rational attack of enough of the triad to make retaliation surely devastating that makes surprise attack seem incredible. In the long run, it is survivability that preserves the stability of the strategic nuclear balance; it is survivability that determines that no decisive, calculable advantage is gained by a first strike.

There are four principal reasons for ICBM modernization (*2*). First, there is the need to reassure our allies and adversaries that the United States still possesses the political resolve to field a weapons system that, like it or not, is considered a principal measure of deterrence and political military might. Second, the decision to have the means to deploy a new ICBM system will have central importance in strategic arms control negotiations. In this regard, the *type* of ICBM—single versus multiple warhead—can be important in determining how the United States and the Soviet Union will, over time, move toward a more stable configuration of nuclear forces at lower numerical levels. Third, there is the value of survivable land-based ICBMs as part of the triad as a hedge against a breakthrough in ASW technology. Finally, the land-based ICBM remains the most controllable part of the triad for prompt and selective nuclear response. There are a host of technical and doctrinal reasons why such selective, prompt, nuclear capacity is unlikely to be provided by a heavily laden Trident submarine, each of which carries about 192 warheads. The capability for prompt nuclear response is judged by many to be especially important for deterring a wide range of Soviet aggression, whether conventional or nuclear. This view is strongly held by some European allies who are eager to avoid the cost of preparing for or enduring conflict in Europe.

It is important to understand that all of these reasons for modernization do not imply the need for a crash program. What is

The author is Provost and in the Department of Chemistry, Massachusetts Institute of Technology, Cambridge, MA 02139.

required is a modernization program that makes strategic sense and a measured schedule consistent with the military and technical purposes required for our ICBM forces. Thus, it is not desirable or necessary today to specify the number of MX or Midgetman missiles that will ultimately be deployed. This number depends upon many factors, among which the most important are the Soviet threat, the results of arms control negotiations, the need to replace aging Minuteman missiles, and, of course, cost.

## Rail Garrison MX Versus the Small ICBM on Hard Mobile Launchers

*System description.* The MX is a large missile that carries ten independently targeted reentry vehicles (thus, it is a MIRVed missile). The MX system consists of the missile and its basing. How the missile is based is critical to assessing the survivability of the missile, and, accordingly, basing has long been recognized as central to the debate over ICBM modernization. The current proposal is to base 50 MX missiles on 25 trains. These trains would remain in garrison on military bases until warning led to dispersal of the missiles on the commercial rail system. Several hours of warning would be required to disperse the MX from garrison on the rail system to require a high number of attacking Soviet missiles to destroy this MX rail-based force. The greater the dispersal, the higher the cost to the attacker.

Because the flight time of an attacking Soviet ICBM is approximately 30 minutes, (for submarine-launched ballistic missiles, the flight time could be substantially less), it is necessary for rail garrison MX to have "strategic" warning in order to survive. Strategic warning refers to the ability to receive and act on information about intention to attack prior to launch. However, the United States and other nations have been notoriously unable to act on strategic warning (*4*). Moreover, in extended periods of crisis, which certainly provide strategic warning, it becomes progressively more difficult to maintain an alert posture. One must guard against an attack not only out of the blue, but also "out of the gray" when the strategic context is ambiguous. And there is the troublesome observation that dispersal of rail garrison MX in times of crisis or in anticipation of attack may itself be destabilizing since it removes an important set of forces from vulnerability to attack and thus may prompt immediate response by the enemy.

It is universally acknowledged that the rail garrison MX system is vulnerable to surpise attack if only "tactical" warning of 30 minutes or less is available from satellite detection of Soviet missile launch, or if other information is available that an attack on the United States is actually under way. Without time to disperse, the concentration of missiles may be destroyed in the Pearl Harbor–like garrisons. Thus, the rail garrison MX system cannot be judged to be survivable to surprise attack. It follows that the system contributes to deterrence of a surprise attack by the threat of launching the MX missiles based only on tactical warning or on information that the United States is under attack. The cost of rail garrison MX systems for research and development, procurement, and 15-year operations for 500 warheads (50 MX) based on 25 trains is about $13 billion in fiscal year 1988 dollars. The cost to rebase the 50 MX now in silos vulnerable to attack by accurate MIRVed Soviet ICBMs is about $4 billion less.

The Midgetman missile is a small ICBM designed to carry one MX-sized warhead to intercontinental range. It is currently assumed that the Midgetman will be based on hard mobile launchers located either at existing Minuteman missile sites located in the northern United States or at existing military bases in the Southwest. In either case, the Midgetman would generate an area of uncertainty for the Soviet planner that would extract an enormous price in warheads required for successful barrage attack, assuming dispersal on tactical warning of approximately 30 minutes. The Southwest basing presents an area of uncertainty sufficient to extract a considerable attack price even in peacetime deployment (*5*). It is universally acknowledged that the Midgetman missile deployed on hard mobile launchers is survivable to a surprise Soviet missile attack in the sense that the attack price to the Soviets to destroy the dispersed, small missile force becomes prohibitively high (*6*). The research and development, procurement, and 15-year operating cost of the single warhead Midgetman system based on hard mobile launchers in the Southwest is $30 billion in fiscal year 1988 dollars; the cost is $2 billion less if deployed on existing Minuteman sites because of savings in logistical support.

*The question of cost.* For 500 warheads the MX rail garrison system costs roughly one-third or $20 billion less than the single warhead Midgetman system based on hard mobile launchers. In times of constrained federal budgets, the argument arises over the question: Does the additonal survivability and the long-term flexibility afforded by the small missile justify its increased cost?

One way of assessing the consequences of this choice is to focus on a realistic appraisal of the opportunities foregone by choosing the higher cost system. This approach has been convincingly pursued by the chairman of the House Armed Services Committee, Les Aspin (*7*), who has analyzed various options for alternative force structures within a *fixed* strategic nuclear forces budget. It is worthwhile to note tht the planned *annual* expenditure for strategic bombers (B-52s, B-1s, B-2s) carrying both gravity bombs and long-range, air-to-air surface cruise missiles (SLBMs), ICBMs, and strategic defense (SDI) is estimated to be $31 billion per year (*7*). Viewed in this context, the difference in cost between the rail garrison MX and the Midgetman on hard mobile launchers is certainly affordable if one is willingly to accept delay in some strategic system (*8*). For example, the difference in cost between these two ICBM modernization alternatives could be funded by delaying the programmed buildup in expenditures for SDI, a program that currently assumes technical progress that could be characterized, charitably, as optimistic.

*Survivability.* The rail garrison MX system does not meet the survivability criterion discussed above. Adequate survivability might be achieved in a hypothetical configuration, in which 50 to 75 percent of the MX-bearing trains were *continuously* moving on the commercial rail system. This would incur an addition of approximately $2 billion over 15 years for operating costs. But no one believes that in the United States it would be possible to have missiles moving continuously throughout the country, bringing nuclear weapons, on alert, into continuous contact with the public.

In contrast, the Midgetman, based on hard mobile launchers, is survivable to the largest credible Soviet attack; they would need to expend almost their total ballistic missile force, equivalent to several thousand warheads, to destroy 500 Midgetman missiles. Analysts believe they would be crazy to do so, given the size of the remaining U.S. strategic nuclear arsenal. Most importantly, from the perspective of the arms competition, the cost to the Soviets to purchase additional warheads to attack a given deployment area for the mobile Midgetman is far greater than the cost to the United States to generate additional land area to reduce damage expectancy, once the land-mobile Midgetman system is deployed. Thus, the Midgetman system meets the central criterion of stability—incremental damage expectancy from additional Soviet deployment can be offset at a lower cost by the United States.

The Soviets, unlike the United States, have maintained a steadily modernized ICBM force over the past two decades. Recently recognizing the value of survivability, the Soviets have deployed *both* a continuously rail mobile heavy ICBM system (the SS-24) and a single warhead small mobile launcher system (the SS-25) (*9*). Of

course, they do not face the same considerations of public interaction with weapon system as do we.

*Relying on prompt launch.* There are those who argue that survivability of the ICBM force is not of great importance because the Soviets would always be uncertain of both our ability and our resolve to launch ICBMs on tactical warning or, at least, after the first confirmed evidence of attack. This uncertainty is seen to contribute as much as deterring Soviet surprise attack as if the ICBM force had the capability to ride out a surprise attack.

The move toward reliance on a launch-on-warning or launch-under-attack strategy is dangerously misguided. Firstly, serious students of history appreciate that acting on tactical warning or on early reports of attack is easier to say than to achieve in practice. Secondly, reliance on prompt launch suggests an inevitable move toward automatic response to intelligence sensor data rather than on informed, human judgment. In the past, American presidents have been reluctant to cede their authority to such a system response by any delegation of launch authority. One reason is a healthy skepticism about the fallibility of even our best intelligence and warning systems; after all, any such system has a false alarm rate. More importantly, no president should wish to have this country's response to a nuclear attack preprogrammed. Such a situation is a certain formula for transforming a catastrophic event (detonation of nuclear weapons on U.S. soil) into certain, total destruction. Thus, while the capability of a prompt launch with survivability adds desirable uncertainty for a potential attacker, reliance on prompt launch without survivability, as a policy, is not only politically infeasible, but also folly of the most fundamental sort.

Elements of the U.S. military are inclined toward a prompt launch policy for understandable reasons. There is the perceived need to cover, with alert ICBMs, the military targets that require prompt destruction, for example, Soviet-fixed ICBM sites and active bomber bases. The target list, which makes up the Single Integrated Operating Plan (SIOP) for general nuclear war, drives the requirement for ballistic missile warheads on alert. Thus, the Strategic Air Command is led to focus on alert warheads and cost per alert warhead rather than on surviving warheads and cost per surviving warhead. Because survivability is expensive, this difference is significant.

*The arms control context.* It is apparent that the requirements for U.S. strategic nuclear forces depend on both the composition and the amount of Soviet nuclear forces. The forces deployed by the Soviets will influence both the character of the threat to U.S. forces and the number of Soviet military targets that must be considered in the planning of possible U.S. responses to nuclear attack. These Soviet forces, of course, also threaten our allies and accordingly influence their attitudes to the force posture that the United States should adopt to deter nuclear war.

For some time, it has been recognized that strategic arms limitations treaties are an important means of influencing the character of the strategic forces of both sides and that it makes no sense to decouple arms limitations negotiations from the planning and decisions about modernization of U.S. forces.

Currently, the United States and the Soviet Union do not have active negotiations under way on strategic arms limitations. The Reagan Administration did undertake a relatively promising set of negotiations subsequent to the successful conclusion of the INF treaty, but these negotiations foundered on two points: Soviet desires to impose limitations on SDI and to eliminate or sharply constrain the development of nuclear-armed, sea-launched, cruise missiles to accompany reduction in ICBMs.

The Bush Administration is likely to seek an agreement that will have as an important objective the reduction of deployed ballistic missiles and a move toward more stable deployment of ICBMs; this means fewer MIRVed ICBMs in fixed silos. It is widely believed that the most favorable outcome expected from this round of U.S.–Soviet negotiations is a reduction by roughly 30 percent of the approximately 10,000 to 12,000 nuclear warheads deployed on strategic systems by each side, with the Soviets accepting a disproportionate reduction in the number of their heavy land-based MIRVed ICBMs.

It is usually assumed that arms control measures necessarily lead to both fewer weapons and more stable force structures; the two do not necessarily go together. An historical example is provided by the birth of MIRVed missiles and the current opposition to MX.

MIRVed missiles are correctly seen to be destabilizing when each side has such missiles based in individual silos. The instability arises because the many warheads on one missile can, in a first strike, destroy several of the opponent's silos and the several missiles they contain, thus achieving a favorable ratio of opponent warheads destroyed to attacking warheads expended.

One might well ask why the United States or Soviet Union deployed such destabilizing systems in the first place. The answer lies, in part, in the inevitable technological imperative in weapons development and in part because multiple warhead missiles are a cheap way to threaten the other side's forces. The answer also lies in part in the incentive created by arms control negotiations. The SALT treaty was based on the fundamental principle of counting and verifying each other's strategic systems. Because for verification purposes it was possible to count launchers and not warheads, launchers became the controlled measure. In the mid-seventies, this contributed to the result of each side building heavy missiles carrying many warheads. A politically salable but technically inappropriate arms control measure contributed to destabilizing deployments. A treaty provision that limited ICBM warheads rather than launchers would have avoided this perverse result.

The judgment that a system is destabilizing depends upon both the basing and the missile. Thus, while it is correct to conclude that MIRVed missiles in silos are destabilizing, it is not correct to conclude that MIRVed missiles are destabilizing and therefore undesirable in all basing configurations. An example is the MIRVed D-5 missile, which is based on a Trident submarine. The submarine preserves locational uncertainty and thus precludes the possibility of preemptive attack. Accordingly, the combination of MIRVed D-5 missiles on Trident submarines is not judged to be destabilizing.

Such inappropriate connections between arms control provisions and technical considerations continue to be made. For example, throughout the Reagan Administration, the U.S. position in START (strategic arms reductions talks) was to ban mobile missiles. Beyond the transparent motivation that the Soviets were deploying mobile systems (the SS-24 and SS-25) and we had none, the reason for adopting this position was that mobility compromised the ability to verify arms control agreements by satellite. Thus, it seems that the United States was adopting the position that easy verification of treaties is more important than encouraging stabilizing force deployments.

Verification has become a critical problem for arms control. We have adopted such strong requirements for verification that the implied technical and operational requirements are not only enormously costly but so complex that effective implementation is most difficult to achieve.

## What Should Be Done?

*Midgetman.* Priority should be placed on production and deployment of 500 Midgetman missiles on individual hard mobile launchers based on military reservations in the Southwest. The incremental

$2-billion cost compared with basing at Minuteman sites is worth the gained independence from tactical warning.

Two additional efforts should be undertaken to enhance the Midgetman system:

1) *A new reentry vehicle (RV).* Currently, Midgetman carries the AIRS guidance system and a single MK-21 warhead, both of which were originally developed for the MX. Research and development on a new, lighter guidance system and a new warhead would lead to an option for Midgetman, which could carry greater payload at full intercontinental ranges. This additional, effective payload could be used for two warheads instead of one warhead or penetration aids (chaff, balloons, decoys) that would increase the probability of penetration of terminal Soviet ballistic missile defenses.

A new RV provides an important option of fielding 1000 warheads instead of 500 warheads on 500 mobile launchers, if future circumstance should call for a larger deployment of total U.S. warheads. Moreover, 250 Midgetman missiles on hard mobile launchers, each carrying two warheads, would cost $23 billion or about $7 billion less than the cost of the equivalent 500 single warhead Midgetman force. This option will be opposed by those who view multiple warhead missiles as destabilizing. As discussed above, this criticism of fixed silo-based MIRVed missiles does not apply to MIRVed missiles based in a manner that preserves locational uncertainty.

2) *Improving the hard mobile launcher.* The success of the Midgetman hard mobile launcher (HML) system depends upon the HMLs operating according to stringent specifications. These include the ability to travel at 30 miles per hour in a wide variety of terrains and to survive blast to 30 psi over pressure. In addition, the HML must have survivable communications and low observable characteristics to avoid surveillance by Soviet space-based or airborne sensors. These areas require attention in an ongoing research and development program. The danger is that, in an effort to drive down the system cost, congressional advocates of the Midgetman/HML system will not devote adequate resources to the HML.

It is worthwhile to note that, because of its relatively small size, the Midgetman is a flexible system in the sense that it can be adapted to many different basing modes; these possibilities should continue to be explored.

*Cancellation of rail garrison MX and the future of MX.* Because rail garrison MX is not survivable, this system should be canceled (I assume that public acceptance of peacetime continuous rail deployment cannot be achieved). This means that additional MX, beyond the 50 presently deployed in Wyoming in converted Minuteman silos, should not be planned for deployment on trains. The priority deployment for the future is Midgetman.

There is no evident role for rail garrison basing except, as discussed below as part of a political compromise, for example, rebasing the original 50 MX missiles currently at Minuteman sites to rail garrison. At a cost of approximately $9 billion, this rebasing of the original 50 MX missiles would provide some additional survivability beyond Minuteman basing, if strategic warning were available.

## Alternative Courses of Action

The choice between Midgetman and rail garrison MX is only the most recent of several proposals to be put forward. For MX, serious consideration has been given to (i) basing in silos, (ii) random transfer between multiple vertical protective shelters (MPS), (iii) random transfer on a racetrack between multiple horizontal protective shelters (Racetrack), (iv) closely spaced super-hard silos (Densepack), (v) placement in deep, underground shelters, and (vi) continuous movement in buried trenches. Many additional MX basing schemes have been studied, each one involving various mixtures of hardness, mobility, deception, and ballistic missile defense, resulting in various combinations of survivability and cost (*10*).

The history of the small ICBM is somewhat shorter, but a considerable number of basing modes have been examined for this system as well (*3*). These include basing (i) in silos, (ii) on trucks or hard mobile launchers, and (iii) on aircraft on alert for airborne dispersal on tactical warning.

After the roughly two decades of attention devoted to the subject of ICBM basing, it is unlikely that a serious candidate basing scheme has not been considered. It is also unlikely that further research and development will uncover a basing scheme that is significantly superior in terms of performance and cost than those already considered. The essential difficulty is that a *political* consensus has not been reached on what the United States needs for ICBM modernization and how much it should be prepared to pay for new capability.

Indeed, previous, credible proposals have been rejected for a variety of reasons, including regional politics (Racetrack), absence of convincing technical evidence at the time of consideration (Densepack), and concern over the implications for strategic arms control agreements (MPS). The program recommended for Midgetman is based on my conviction and that of others (*11*) that survivability for land-based ICBM forces is worth the considerable, additional cost. Not all will agree. Accordingly, it is reasonable to ask what alternative courses of action are likely to be considered and why. There are four: (i) do nothing, (ii) deploy less, (iii) place Midgetman in silos, and (iv) deploy MX in a variant of MPS called Carryhard. Each of these alternatives has its advocates and represents various compromises between ICBM survivability and cost.

*Do nothing.* There are thoughtful experts and members of Congress who believe that little or nothing should be done to modernize the U.S. ICBM force. This view is based on observations about technical and political developments. First, given the accuracy achievable at intercontinental ranges, simple silo basing will not provide adequate survivability even at an astounding level of hardness. And as long as MIRVed missiles are permitted, it will always be favorable to attack a silo with two warheads in order to destroy one missile. In a world where only single warhead missiles were permitted, this would not be the case. Instead of incurring the substantial cost to achieve survivability of land-based ICBMs, it is argued that it would be better to rely on submarine ballistic missiles (SLBM) for any prompt, hard target capability judged to be required for deterrence. Technically, the D-5 missile on Trident submarines is sufficiently accurate to provide this hard target capacity. If survivable communication can be established and an appropriate doctrine adopted, the SLBM alternative can be viewed as providing survivable (assuming no ASW breakthrough), ballistic missile incremental capability at lower cost than the Midgetman alternative. The essence of this argument is that the technical advances of ballistic missile accuracy has made ICBM land-basing obsolete, and the United States should move to a strategic force composed of SLBMs and bombers.

There is also an important body of political opinion that holds that the United States has enough strategic nuclear forces in its bombers and SLBMs to assure deterrence and that no modernization of the existing Minuteman force is required, especially given the recent attitudes of the Soviet Union under Gorbachev. While it is unlikely that those supporting this view have sufficient congressional support to achieve a vote against ICBM modernization, they can legitimately regard delay as victory. Given the disarray among the many competing advocates of the different ICBM modernization alternatives, the advocates of the do-nothing option may well win

the day. This is unfortunate because such an outcome is not the result of reasoned debate about the need for ICBM modernization but rather the result of confusion about what kind of ICBM modernization should be undertaken and why.

*Deploy less.* Most recently, President Bush has proposed a compromise to break the impasse on ICBM modernization. The proposal has all the characteristics of successful compromise in Washington—no single element is ideal, everyone gets something they want and so can declare victory, and certain issues are put aside for another day.

The compromise proposal would abandon the deployment of an additional 50 MX missiles. The 50 MX missiles currently in silos would be rebased into rail garrison, thus affording some additional degree of survivability. Most importantly, a commitment would be made to the prompt deployment of 300 single warhead Midgetman missiles on hard mobile launchers. The virtue of this proposal is that it is relatively affordable.

The weakness of the compromise is that it proposes early deployment of rail garrison MX, beginning in fiscal year 1992, and later deployment of mobile Midgetman, beginning fiscal year 1997. This is not a convincing commitment to mobile Midgetman. Many Midgetman supporters will understandably doubt the Administration's willingness to pursue the program in the future, especially in the early nineties when defense budgets may be even tighter, and the Midgetman program begins to need substantial procurement dollars. These doubts are strengthened by the known opposition to the small missile by both Secretary of Defense Richard Cheney and the Air Force.

The advocates of rail garrison MX would support the rebasing, as the prospect for further MX deployment would not be foreclosed if future conditions warranted it. In large measure, this would depend upon the results of strategic arms limitation negotiations. At the same time, advocates of the mobile Midgetman system would see the Department of Defense adopt the Midgetman as the ICBM system of the future.

In its spirit, the proposal is not very different from the original recommendations of the Scowcroft Commission (*2*); it has the desirable feature of a somewhat more survivable basing for the MX. The total number of deployed warheads is substantially less than that advocated by the Commission (which advocated the deployment of 500 mobile Midgetman and 100 MX missiles in Minuteman silos), but this is not a serious difference, especially if a reasonable arms treaty can be negotiated. This compromise deserves, and certainly will receive, serious consideration.

As estimate of the cost of this proposal is $34 billion—approximately $9 billion to rebase the 50 MX and $25 billion for deployment of the 300 Midgetman missiles. Thus, the proposal is cheaper than deployment of both 50 new MX and 500 mobile Midgetman missiles, but about the same as my proposal.

*Midgetman in silos.* Midgetman supporters have recently put forward another compromise proposal. These advocates are concerned that the high cost of mobile Midgetman will deter Congress and the Administration from adopting an ICBM modernization program that makes strategic sense. Their compromise modernization program is intended to minimize costs in the short run and still preserve the possibility of deployment in a more survivable mobile basing mode in the future.

The proposal is to deploy 500 Midgetman, either in Minuteman silos or in new silos of moderate hardness. It is argued that, while less survivable than mobile basing, this deployment is certainly a great deal more survivable than 500 MX warheads in 50 silos or in rail garrison. Moreover, the 500 silo aim points of such a deployment would require an attack of at least 1000 warheads for successful destruction, thus absorbing roughly 100 SS-18 missiles—about one-third the present inventory and two-thirds of the post-START inventory of this modern, heavy Soviet ICBM. If arms talks bring down the permitted ICBM warhead total, the attack price of 1000 warheads represents a significant deterrent to Soviet attack. In sum, the compromise silo deployment for Midgetman is asserted (i) to provide significant near-term deterrent value; (ii) to maintain for the future the higher cost-basing option for Midgetman if additional survivability is considered desirable and affordable; and (iii) to be significantly cheaper than the hard mobile launcher alternative for Midgetman.

This position is marginally acceptable if, and only if, the cost savings between silo and mobile basing are significant. The current estimate in fiscal year 1988 dollars to place 500 Midgetman missiles in silos is approximately $24 billion (*12*); this includes required research and development, procurement of missiles and silos, and 15 years of operation. The sum should be compared to the $28- to $30-billion cost for the hard mobile launcher deployment. If this difference in the cost estimates for the two deployments is accurate, then the compromise Midgetman deployment in silos makes little sense. Simply put, no one would be willing to forego the survivability advantage of the hard mobile launcher deployment for $6 billion in lifetime cost (*13*). Moreover, there is no indication that the silo deployment would have significantly lower up-front costs that would make it politically attractive in this time of tight defense budgets.

Is the $6-billion differential reasonable? The question points to one of the serious problems facing in defense planning. There is a tendency for cost estimates to be based on assumptions that reinforce the prevailing policy position. For example, Air Force opposition to Midgetman led to inflated cost estimates (over $50 billion in contrast to the current $30 billion), but these estimates are now falling like a stone in the face of strong congressional support for the system.

The differential is sensitive to the very uncertain estimate of operating costs for each of the two systems. However, based on presently available information, it is by no means clear that the cost savings to be realized by silo basing of Midgetman are sufficiently significant to select this basing mode over the more survivable hard mobile launcher.

*MX in Carryhard.* Since MX based in Minuteman silos or in rail garrison does not possess adequate survivability, it is worth inquiring if there is any reasonable basing mode for MX that would have adequate survivability and the comparison of the costs of such a system to mobile Midgetman. Veteran observers will be amused by consideration of an MX alternative because they correctly believe that there is an insurmountable bias against MX in Congress, but the option should be examined.

If an MX missile is randomly moved between ten silos in such a way that the enemy cannot discern the location of the missiles and must attack all ten aim points in order to assure destruction of the MX, then one has achieved a basing configuration equivalent to ten Midgetman missiles in silos from the point of view of survivability. This is the idea of vertical, multiple, protective shelters (MPS), which for many years has been recognized as a successful method of increasing the survivability of a MIRVed missile. Assuming that the locational uncertainty can be preserved, there is no compelling reason of stability to prefer ten Midgetman missiles in silos to one MX missile based in vertical MPS moved randomly among ten aim points. If the cost of the single, large MX plus its ten, large vertical shelters is less than the cost of the ten Midgetman missiles plus their silos, there may be a reason to prefer the MX vertical MPS to the equivalent Midgetman silo force. Because small missiles are likely to cost a great deal more than empty large silos, this cost comparison can well turn out to favor the MX alternative.

In recent years, the cheapest way to accomplish vertical MPS for MX has been by a scheme referred to as *Carryhard*. In this scheme, the MX missile is placed in a hardened cannister containing the required operational support systems, and the missile in its cannister is moved between relatively austere and cheap vertical shelters.

In order to compare Carryhead MX basing with Midgetman missiles on hard mobile launchers based in the Southwest, it is necessary to calculate that number of independent aim points required to extract an attack price of attacking Soviet warheads, which is equal to the attack size the Soviets would need to barrage the area occupied by the mobile Midgetman force. The cost of 50 MX missiles based in Carryhard with the required number of shelters is $21 billion. This is an analytically respectable alternative to consider because it provides adequate survivability at an appreciable cost savings.

Most knowledgable observers place significant emphasis on the greater flexibility provided by a small missile. There is also considerable sympathy for adopting as the nation's new ICBM a small missile, which, over time, could and should be adopted by both the United States and the Soviet Union as the central element of a land-based ICBM force. How the Bush Administration and Congress answer the ICBM modernization question will be a significant indicator of our government to resolve difficult national security issues in the foreseeable future.

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8. Other cost differences should also be considered. For example, the Air Force is correctly concerned with the larger need for uniformed personnel to support the mobile Midgetman.
9. *Soviet Military Power* (Department of Defense, Washington, DC, 1988).
10. In 1981 and 1982, Charles Townes of the University of California at Berkeley chaired two committees for the Secretary of Defense to evaluate possible MX basing modes. A more accessible adequate source is *MX Missile Basing* (Office of Technology Assessment, Washington, DC, 1981). An interesting series of articles on ICBM basing by Antonia Chayes, Russell Dougherty, Donald Hicks, Jan Loedel, Jack Ruina, and John Toomay may be found in *International Security* **12**, 152 (1987).
11. A viewpoint is presented in (*2*) and more recently by Brent Scowcroft and R. James Woolsey, in *American Agenda: Report to the Fifty-First President of the United States of America* (Washington, DC, 1988).
12. Here and elsewhere in the paper, cost estimates are obtained from sources the author believes to be reliable. The estimates depend on many assumptions and should be considered to give an impression of relative, not absolute, costs. System cost estimates are given in fiscal year 1988 dollars, undiscounted, and include remaining research and development, procurement, and 15-year operating expenses.
13. The difference in cost arises largely because of the higher operations and maintenance expenses of mobile basing compared with silo basing.


# Optimum Chemical Sites and Techniques for Searches for Negatively Charged Rare Particles


R. N. BOYD, K. TAKAHASHI, ROBERT J. PERRY, TERRY A. MILLER



**Supersymmetric particle theories have predicted the existence of massive, negatively charged, nonstrongly interacting particles, denoted as $X^-$ particles. If stable $X^-$ particles existed at the onset of primordial nucleosynthesis, they would have been bound initially to the primordial nuclides. However, subsequent stellar processing, as part of the chemical evolution of the galaxy, is shown to have produced considerable rearrangement of the relative chemical abundances of $X^-$ particles subsequent to their binding to primordial nuclei. Optimal chemical environments in which to search for $X^-$ particles are found to be boron and fluorine. A mass-independent search for $X^-$ particles bound to heavy nuclei that utilizes laser spectroscopy of rotational bands in diatomic molecules is estimated to have an unusually high relative sensitivity to possible $X^-$ particles.**


ONE OF THE FASCINATING PREDICTIONS RESULTING FROM attempts of particle theorists to unify the forces of nature is the possible existence of supersymmetric (SS) particles (*1*). Although SS theories have generated considerable attention, their ultimate reality depends on the existence and observation of at least some of the predicted particles. Attempts (*2, 3*) to produce these particles in high-energy interactions have thus far been unsuccessful, but they have set an apparent lower limit on the masses of such particles of about 25 GeV (masses are given as $mc^2$, where $c$ is the speed of light, with the proton mass being 0.938 GeV in these units).


R. N. Boyd is in the Departments of Physics and Astronomy, Ohio State University, Columbus, OH 43210. K. Takahashi is at the Institut d'Astronomie, d'Astrophysique, et de Geophysique, Universite Libre de Bruxelles, B-1050 Bruxelles, Belgium. R. J. Perry is in the Department of Physics, Ohio State University, Columbus, OH 43210. T. A. Miller is in the Department of Chemistry, Ohio State University, Columbus, OH 43210.