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STRATEGIC DEFENSE AND ANTI-SATELLITE WEAPONS

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STRATEGIC DEFENSE AND ANTISATELLITE WEAPONS

WEDNESDAY, APRIL 25, 1984

UNITED STATES SENATE,
COMMITTEE ON FOREIGN RELATIONS,
Washington, D.C.

The committee met, pursuant to notice, at 10:06 a.m., in room SD-419, Dirksen Senate Office Building, Hon Larry Pressler presiding.

Present: Senators Percy, Pressler, Pell, Biden, Glenn, and Tsongas.

Senator PRESSLER. If I may begin. Today's hearing is the fourth in a series on space weaponry and arms control.

When we began this process in 1982, space weaponry attracted little attention. Times have changed. Since then, the United States has begun advanced flight tests of an F-15 based antisatellite weapon [ASAT]. Press reports indicate that this weapon will be launched at a space target next fall.

In 1982, the notion of space-based or space-directed energy beam weapons was known to only a handful of specialists. Today, Congress is being asked to fund a 5-year, $26-billion effort. This effort is little more than the first downpayment on a program requiring $500 billion to $1 trillion to complete.

Today's hearing will consider both the immediate concerns raised by ASAT weapons and the long-term implications of futuristic strategic defenses.

With regard to ASAT, I believe the United States is best served by arms control talks. If the Soviets are as serious about ASAT negotiations as they claim to be, then our governments can reach agreement on effective verification. The contention that an ASAT ban is unverifiable rests on an unrealistic standard of verification.

Space arms control must seek to ban or very strictly limit the greatest threats to our satellites. Controls on the Soviet SS-9 ASAT and on high energy laser facilities can be verified. Defensive countermeasures, rather than arms control, can protect against the lesser threats of jimmy-rigged and untested systems. If we can do away with the most sophisticated ASAT threats, countermeasures can help to do away with latent ASAT capabilities.

Many specialists believe that a ban on dedicated ASAT's can be verified since they are associated with known launch facilities. Similarly, we can monitor strict limitations on high energy lasers. They are few in number. Therefore, unlike a so-called comprehen-

sive ASAT ban, restraints on the most direct threats to satellites are verifiable.

Such an approach is consistent with the verification standards applied in the START [strategic arms reductions talks] and INF [intermediate-range nuclear forces] talks. If we were to demand comprehensiveness in nuclear arms control, there would be no hope of ever reducing nuclear weapons. If verification standards currently applied to ASAT arms control were applied to nuclear arms control, we might refuse to negotiate while commercial airliners remained in operation. Airliners have a residual capability to deliver nuclear weapons, just as any satellite jimmy-rigged with explosives potentially can attack U.S. satellites.

Fortunately, attacking satellites is a complicated task. The Soviet ASAT's dismal test record, of 11 failures in 20 attempts, is testimony to the difficulty of satellite attacks, even by a dedicated system.

If we can rid ourselves of the dedicated Soviet ASAT and strictly limit the major threats confronting U.S. space systems, countermeasures can manage much of the rest. Without restraints, countermeasures could prove useless.

In the area of ballistic missile defense, the possibility of ever producing a total defense against nuclear attack "is so remote that it should not serve as the basis of public expectation or national policy." This is the view held in an Office Technology Assessment [OTA] paper released yesterday. We will be hearing more about this today. I agree with it and believe that the United States would be better served by arms control for these space weapons.

It is evident from congressional testimony that many Defense Department specialists are equally skeptical on the feasibility of a total defense. More and more, Pentagon officials point to the technological hurdles that must be overcome before advanced missile defenses will be possible. At the same time, less is being said about people protection. Protecting missile silos against nuclear attack has begun to replace population defense as the justification for developing beam weaponry.

Some people have asked: "Isn't reducing the vulnerability of our missile fields a sufficient reason for going ahead with research on advanced ballistic missile defenses?" My reply is this. If we wanted a defense for the MX, Congress would have funded the $35 billion Densepack plan. If a $35 billion Densepack missile protection concept made no sense, a trillion dollar beam-powered missile defense makes even less sense.

I support research on defenses as a prudent hedge against a Soviet technological breakthrough. But the program proposed under the Strategic Defense Initiative [SDI] goes well beyond requirements for keeping pace with Soviet activities. Moreover, the SDI would not help the United States address the short-term Soviet breakout risks. The fruits of the SDI are at least two decades away. Expanding U.S. futuristic defense programs has diverted resources away from more traditional ballistic missile defense concepts. This may leave the United States exposed to Soviet challenges between now and the year 2000.

In summary, the risks and costs of a space weapons race could prove to be extremely high. At a minimum, the United States

needs to think long and hard about the implications of a space arms race. Through talks with the Soviet Union, we can determine whether space arms control can contribute to our Nation's security.

Today we are fortunate to have a large number of distinguished witnesses. But first, I would like to call on other members of the committee who have worked in this area a great deal.

I will first call on whoever would wish to go first.

The CHAIRMAN. I ask for regular order, Mr. Chairman. Senator Pell is next.

Senator PELL. Mr. Chairman, I am an original cosponsor, and am very glad to be one, of Senate Joint Resolution 129, bearing on the subject covered here this morning.

At my suggestion, the resolution calls for a mutual, verifiable moratorium of limited duration on the testing of antisatellite weapons against objects in space.

Senator Pressler has authored the call for a bilateral agreement on antisatellite weapons, and, at Senator Tsongas' suggestion, the resolution looks beyond ASAT's to call for a comprehensive ban on space-based and space-directed weapons.

That resolution was approved unanimously last year by our committee, and I would hope for floor consideration in the not too distant future.

In contrast with this congressional initiative, the administration has expressed its reluctance to seek a comprehensive ban on antisatellite weapons, claiming that verification requirements prevent progress. In addition, the Pentagon clearly has its heart set on a whole new array of space weapons.

I welcome the opportunity this morning to learn more, first hand, about the administration's rationale for slowing down and dragging its feet on space arms control.

Our outside witnesses can help us reach a judgment on what space-related arms control they believe is possible, on what priorities they would set. I hope Congress will have the wisdom and the foresight to apply the brakes now, before we are too far along to turn back from the present rush to "Star Wars."

Our earlier experience with MIRV's [multiple independently targeted reentry vehicles] should have taught us that arms limitation often is smarter than the head-long pursuit of new weapons systems.

I remember as vividly as if it were last month the original discussions about MIRV's and how the administration at that time wanted us to go ahead because we had a slight edge. We went ahead and found the Soviets had soon caught up with us. I now believe all hands would be delighted if we had not MIRV'd those years ago.

The space race we now are confronting could involve similar incalculable costs and great peril.

Thank you, Mr. Chairman.

Senator PRESSLER. Thank you.

Incidentally, we do have a commitment to get that resolution up by Memorial Day——

Senator PELL. Great.

Senator PRESSLER [continuing]. Thanks to Senator Percy's letter to Senator Baker.

Senator Percy.

The CHAIRMAN. Senator Pressler, it has been less than a month since we received the administration's report on its policy on antisatellite negotiations, and we have just received the report, "Directed Energy Missile Defense in Space," which is a background paper prepared under contract for the Office of Technological Assessment.

I presume that you have had a chance to scan that background paper by Dr. Ashton Carter of the Massachusetts Institute of Technology.

Neither one of those reports really provides much comfort for the reader. The administration report notes that test bans for selected types of antisatellite weapons might be verifiable. The report also observes that verification problems could be mitigated by new technologies or by cooperative measures that might be reached in future arms control agreements.

Unfortunately, having left the door open for at least modestly constructive antisatellite negotiations, the administration seemingly still refuses to walk through that open door. I cannot personally agree with a report which concludes that urgently required proposals for preventing an arms race in space must necessarily remain under study for what might appear to be an indefinite period. I just don't think time permits such an extended study.

This is 1984, not 1981, and the administration has had over 3 years to develop an effective strategy for space arms control. During these 3 years, time has not been standing still. On the contrary, the Soviets have continued to improve their existing operational ASAT system, and the United States has now begun testing of its own minature vehicle [MV] ASAT.

Even more disturbing, the administration has formalized the so-called Strategic Defense Initiative, which raises grave questions as to its cost, goals, technological feasibility, effect on crisis stability, and consistency with long-standing arms control policy.

In the late 1960's, together with Senator John Sherman Cooper, other members of this committee, and, certainly on the floor, Senator Proxmire, I decided after a tremendous amount of study—we had a couple of years into the study of the antiballistic missile [ABM] system—to vigorously oppose the proposed deployment of the Safeguard ABM.

At that time, I was convinced that whatever investment the United States made in strategic defensive weaponry would inevitably have been overtrumped by additional Soviet investments in relatively less expensive offensive systems.

Every bit of arithmetic we did showed that you could always build at least one more offensive weapon far cheaper than you could continue to build defensive weapons. You would just keep going up and would escalate. I did not know of anything that would escalate the nuclear arms race faster than going ahead with that system which, if I recall correctly, had a capital cost of about $75 billion, but an operating expense then estimated—a decade ago—of $10 to $15 billion a year.

I have never been happier about a decision to fight that right down to the end on the floor, right up to Christmas Eve one year,

and to finally get a vote on that, end it, resolve it, and put it behind us.

I don't see a strong body of support for resurrecting that.

The net result would have been that each side would have spent tens of billions of dollars simply to maintain the strategic stalemate at a much higher, more costly, and less stable level.

I am deeply concerned that the administration's SDI proposal repeats the error of the original ABM deployment proposal 15 years ago. In light of determined Soviet research and development efforts in directed energy weapons programs, the United States must maintain a prudent level of R&D in these areas as a hedge against a possible Soviet breakthrough. But there is a great difference between a hedge and a top priority development program that is designed to lead to a deployment decision.

In a report released last month, General Scowcroft and the commission that he headed warned, "Extreme caution should be applied before plunging ahead with the SDI." I simply could not agree more.

That is why there is great importance in your appearance here today and our conducting this hearing.

I believe that the United States should exercise extreme caution before it deploys its ASAT or invests tens of billions of dollars developing other space-based or space-directed weaponry.

One element of a policy of caution is arms control. I do not know if arms control can succeed in the ASAT area. We simply do not know. In START and INF, we have made very little progress, particularly now with the walkout of the Soviets and their total unwillingness to even sit and discuss seriously these areas and the proposals we have made. So we don't know what kind of progress we are going to make with ASAT's.

It could be that the Soviets would reject all our proposals for effective verification of a total ASAT and space weapons ban. It could be that we would have to settle, for the time being, for a partial ban, one that only prohibited high altitude, antisatellite weapons.

But I do know that we should try. I don't see how we can just assume that we can't succeed. We ought to move ahead and at least try, if we fail, then we fail. But we ought to try in every way we can to succeed.

I cannot fathom why the administration is willing to propose a total ban on chemical weapons, which I fully support, with all the challenges for verification that this entails, and yet it remains unwilling to do the same with antisatellite missiles.

I hope that we can get some answers and clarification from our distinguished panel this morning.

Senator PRESSLER. Thank you very much.

Senator Tsongas.

Senator TSONGAS. Mr. Chairman, let me begin by commending you for having these hearings. They are obviously of interest at this time.

I think the hearings are going to be even more important to historians. When people look back at this era and try to understand how this all happened, these hearings will be very important.

Mr. Chairman, the fact is that we have sat here through the Haig era, and I remember discussions with him about getting the START talks going, and how long it took to get that to move; also during the Adelman period, when he said to us that he was going to show that he was a true disciple of arms control, and the months went on and on and on, and nothing happened.

History will not treat this administration kindly. There has been no progress on arms control.

What are we talking about today? It is not a treaty of some sort, but a new development—extending the arms race into outer space.

Historians do not care about great communicators. They care about results. I think history will be the final arbiter of this kind of policy, assuming there are any historians left to write it.

In the last decade, there used to be a great deal of discussion by sociologists as to whether there was any such thing as a bad boy. Here we are, in the 1980's, with strategic thinkers, some of whom believe there is no such thing as a bad weapon, that any weapon, no matter how ill-conceived, is something that we ought to pursue.

I would like to ask the witnesses in advance to consider the two statements made by the two highest officials in this country. The President said that the "Star Wars" system would "render nuclear weapons impotent and obsolete." That is what he said. I want each witness to comment on whether indeed they share that view, specifically. The second statement is by Caspar Weinberger, who said that they were going to develop a system "thoroughly reliable and total."

I would like the same response to that statement as well.

This fantasy has been sold to the American public long before anybody had any idea as to its detail. I would like to hear, especially from our first witness, how this thing got conceived, who sold it to the President, and what advice did the President get during that period of time. I think history has a right to know that. In time, we will be fascinated by the process that we are talking about here today.

Thank you, Mr. Chairman.

Senator PRESSLER. Thank you very much.

Senator Glenn.

Senator GLENN. Thank you, Mr. Chairman, but I have no opening statement.

Senator PRESSLER. Let me say that I think the world is on the verge of a new, major arms race which might be preventable if we did have talks with the Soviets. This is one area where the new Soviet leadership has indicated they would have talks. Whether or not that is sincere is something we should test.

In any event, we are fortunate today to receive testimony from a number of witnesses. Our first panel will consist of Dr. George A. Keyworth, the President's Science Adviser; Lt. Gen. James Abrahamson, the newly appointed head of the Strategic Defense Initiative Programs; and they will be accompanied by several DOD officials.

We will also hear from Ambassador Robert Buchheim, the U.S. ASAT negotiator in 1978–79; Dr. Sidney Drell, of Stanford University; and Prof. Albert Carnesale of Harvard University. Finally, the

Office of Technology Assessment will testify on its study of ballistic missile defense which was released yesterday.

I would ask that Dr. Keyworth testify first. He will be joined at the table by General Abrahamson and other DOD witnesses.

We would also ask that statements be limited to about 10 minutes duration, though, if needed, we will take as much time as necessary since this is such a serious subject. If you need more time, we will try to accommodate you. We will certainly insert all of your statements into the record.

Dr. Keyworth.

STATEMENT OF GEORGE A. KEYWORTH II, SCIENCE ADVISER TO THE PRESIDENT

Dr. KEYWORTH. Thank you very much, Mr. Chairman.

Thank you for inviting us to discuss the President's Strategic Defense Initiative and its relationship within our arms control efforts. I hope we can, together, clarify some of the doubts and concerns that you have raised.

I believe the Strategic Defense Initiative is, in fact, key to these efforts, and a means by which we can provide hope, not only to America and her allies, but to a world which is watching us as well.

This hope is one which the President challenged both the scientific and arms control communities to bring to fruition. I would remind this distinguished audience that he linked the two inexorably together in his oft misquoted March 23 speech of last year. I quote: "I am directing a comprehensive and intensive effort to define a long-term research and development program to begin to achieve our ultimate goal of eliminating the threat posed by strategic nuclear missiles. This could pave the way for arms control measures to eliminate the weapons themselves."

It is, therefore, imperative that you understand from the onset that the Strategic Defense Initiative is not a search for a technical panacea. It is a search for a technical tool by which different peoples, with different political bonds and cultures, can find a common ground to negotiate a common peace.

With all the rhetoric that has passed back and forth over the last year, one might ask, "Is there much left to say?"

In fact, what has been said from various quarters has confused things more than clarified them.

But, as with any issue that touches on nuclear arms control, the prospect of strategic defense has produced strongly polarized camps. One side says that we can produce technological marvels that will make us safe from nuclear weapons—and today—at incredibly low prices. The other side rejects the technological ability to ever do anything which will substantively affect the outcome one way or another, and claims that the price of demonstrating that failure will cost perhaps trillions.

Now, I don't want to get into either extreme today, other than to reject both of them as exposing our real national capabilities to undue criticism.

Instead, I want to focus on the real question: where are we going with this program?

If I were forced to a single sentence answer, it would be: "We see the investigation of strategic defense options as an absolutely vital catalyst to real arms control."

To see why, I refer to the conclusions of the gentlemen most often identified with this effort. They are the President, who issued the challenge, and Dr. Jim Fletcher, who chaired the first response to that challenge. The Fletcher team's first formal conclusion sets the stage. It is, in my opinion, a most eloquent summation of our capabilities and objectives. I quote: "Powerful new technologies are becoming available that justify a major technology development effort to provide future technical options to implement a technical strategy."

It is an authoritative conclusion, as much for what it does not say, as for what it does say. After 5 months reviewing our complete technology base, more than 50 nationally ranked scientists and engineers concluded that these capabilities are on the horizon.

No, they are not here now, especially if defense against long-term unconstrained Soviet threats and countermeasures is specified as our immediate goal. But even those defensive capabilities are coming, and are foreseeable, which is a major difference between the mid-1980's versus the mid- to late-1960's. They are coming. Whether we like it or not, those technical advances are occurring.

The advance of knowledge is one area in which national institutions have been singularly unsuccessful in attempting to repress or control. It has sometimes been slowed down, but history is replete with examples where such knowledge finally bursts through the seams and goes its way, inevitably favoring those who have had the foresight to accept change and mold it to their benefit.

This is especially true in the case of those technologies associated with defense. It is not so much that we deliberately tried to develop defensive capabilities. In fact, such specific development has been severely hampered by our own self-imposed restrictions. Rather, these capabilities are a natural byproduct of our civilian industries and universities, as they are to a somewhat lesser extent in the Soviet Union.

It has been the incredible leaps in data processing, as much as any single area, which has fueled this explosion. And it is not just that we no longer need mammoth warehouses to contain the radars and computers necessary to the ABM of the 1960's. The very existence of today's and tomorrow's ability to solve complex problems on incredibly small machines, and fast, has opened up the development of our entire national technical base.

What is more, the availability of these machines has made this capability accessible to hundreds of thousands of institutions, industries, small companies, and individuals.

It was data processing which overcame John von Neuman's skepticism of ever making the ICBM work in the first place. It was data processing at the heart of the move to MIRVing. It was data processing which tied ICBM fleets together for coordinated execution. It was data processing which has provided the ICBM accuracy necessary for preemptive strikes. And it is data processing which will be at the heart of any defense against ballistic missiles.

Therefore, whether he intends to or not, man is rapidly moving toward the technologies necessary for strategic defense. The movement is widespread, and pervades every aspect of even our daily life. "Powerful new technologies," I quote again, "are becoming available," as the Fletcher panel noted.

The plausibility of such technologies makes it imperative that we investigate the development of these defensive capabilities. It does not yet mean we must commit to their deployment.

Neither our technology nor our policy is sufficiently mature to immediately take such a step, and we have not advocated such a move. We need to answer vital questions on the survivability of any space-based assets we may find necessary.

We need to dramatically improve the performance of our directed-energy—lasers and particle beams—as well as conventional and other high velocity nonnuclear defensive technologies. We also need to further develop our surveillance/acquisition and tracking capabilities, and determine the levels of confidence we could place in such technologies.

In short, we need to know what our future technical options are.

We also need to explore our policy options. There is no intent to suddenly shift our policy deterrent posture in relation to either our allies or our adversaries. We have neither the capabilities nor the information on which to base such a move. At the same time, to cast into concrete for all time the incredible scale of destruction now facing us is intolerable.

We seek a solution which eventually enables us to realistically discuss—not deep—but drastic cuts in the offensive nuclear arsenals. The decision to implement effective defenses as part of that solution will be that of our successors and will have to combine arms control and gradual shifts in offensive weapons types and postures on the part of ourselves, our allies, and the Soviets. Such decisions can only come as the result of informed consultation between the executive and legislative branches, and we cannot leave our successors informed choices if we do not move rapidly to develop these options.

We have had relatively few strategic options for more than a decade now. Ever since the early 1970's, both sides have concentrated on improving and increasing existing offensive technologies. At the same time, neither side has had much luck in negotiating meaningful arms control. I don't find this hard to understand at all. An unobstructed view down your adversary's gun barrel does tend to limit your vision.

I, therefore, have been desperately searching for a way, along with many others, to make a mutually verifiable build-down process really work. I say this because the Soviets' last 10 years of constant modernization have left them with an enviable legacy. Most of their systems are fairly up-to-date; conversely, most U.S. strategic systems are not. I say this because I do not believe any present or future nuclear power will ever voluntarily reduce their arsenals to zero, and it will take a verifiably near-zero arsenal, in the absence of effective defenses, to make a real difference in the hopelessness our children feel today.

At the same time, there is a vast difference in perception between the United States and the Soviet Union of what these arse-

nals are for. The United States has built a balanced triad of forces, ICBM's, SLBM's, and bombers. We have structured this force since the 1960's on the basis of peacetime deterrence to prevent war.

The Soviets, on the other hand, have apparently structured their force almost exclusively as a war fighting machine in the event of war. Their reliance on otherwise vulnerable ballistic missiles, their massive investment in civil and military passive defenses, their posture statements, and their exercise data all point to an abiding belief that they must always be able to preemptively strike U.S. forces and thereby prevent their use. Because of the same balance in both force structure and vulnerability, however, both sides perceive the other as striving for a first-strike disarming capability. In light of this I am not surprised that we have had a very difficult time trying to find a common negotiating ground.

I am also not surprised that the Soviets have been working extremely hard on the very defensive technologies the President's critics have labeled "fantasy." Some have gone so far as to state the Soviets are far ahead of us in these areas. I believe, in fact, it is more the case of the tortoise and the hare. The Soviet tortoise, slow but sure, may have in fact passed the dozing U.S. hare in some areas, particularly in the large-scale demonstrations of directed energy and particle beam work. But the hare still owns the basic technological muscle of manufacturing and materials technology, high-energy, physics, aiming/point/and tracking—and that all-important area—data processing.

If only he will get up and move.

This is the President's greatest worry. In his March 23 speech of last year, he expressed his concern that defensive systems, coupled with offensive systems, could be perceived as aggressive in nature. He has elaborated on that theme several times since, in that regardless of the moral issues at stake, he recognizes an inevitability to the arrival of defensive technologies. They are becoming available, like it or not.

We can, therefore, take either an optimistic or a pessimistic view here. An optimist would have the United States leading the development of such defensive capabilities. This provides future options for future Presidents and the Congress.

Options to approach the Soviets and, if warranted, negotiate very carefully phased development of mutual defensive capabilities.

Options to begin disarming the perception, if not the fact, of each other's first-strike capability.

Options to begin reducing the arsenals which would then realistically have only retaliatory capability.

Options to step in and break the cycle which has produced a standoff in meaningful offensive arms negotiations for more than a decade.

The pessimist, on the other hand, would have the Soviets march inexorably ahead and produce the first series of demonstrable defensive capabilities. I personally have little doubt as to whether the Soviets would then offer us a similar set of options.

I do not offer this scenario lightly. Moving out from under the nuclear umbrella is a serious and most expensive prospect. Neither our military structure and organization, nor our technology is

ready for it now. The Strategic Defensive Initiative is not the end-all answer, but it is the catalyst.

So far, I have dwelt primarily on defending against ballistic missiles. Please do not infer that we consider submarine, air-breathing, or tactical nuclear weapons any less deadly. They are also to be addressed within the Defense Initiative. But the ICBM, as it has now evolved, is by far and away the most dangerous to stability in a crisis, and it seems to generate the most hysteria, whether the subject is defense or offense.

The ICBM is now the strategic weapon of choice for the Soviet Union and is predicted to remain so by all of our intelligence projections. If we are to have any hope of affecting real arms control, we must first address the ICBM. We have begun that process with the strategic modernization program. It alone faces the Soviets with the evidence that their ICBM's must begin to evolve to more survivable designs, and these designs preclude monster missiles like the liquid-fueled SS-18.

The prospect of effective boost-phase defenses subsequently shuts off the option of leaving those heavily MIRV'd missiles in their vulnerable silos and using them preemptively, and the anticipation of layered defenses cripples realistic thought of moving en masse toward those light-weight, fast-burn, heavily armored generations of responsive Soviet ICBM's projected by some critics.

I therefore have three summary observations on such responsive moves by the Soviets:

First, any such move may have to be accompanied by as much as a tenfold decrease in their warhead payload.

Second, it could mean complete rebuilding of their entire intercontinental ballistic missile fleet—75 percent of the Soviet strategic investment.

Third, I invite you to ask the people who build ICBM's for a living—that is, the Boeings, the Martins, the Rockwells, the aerospace corporations—just how simple and cheap it would be to rebuild such an ICBM fleet to an unknown specification and from scratch.

The immediate requirement for the Defense Initiative management is then to reorganize the divergent programs which now exist within two Cabinet-level departments, three military services, two agencies, three Federal labs, and a host of university and industrial concerns. Their immediate task is to ask themselves, as I did, where are we going, and then get set for the long haul.

Last week, Secretary Weinberger centralized his management with the appointment of Lieutenant General Abrahamson as its Director. General Abrahamson is already well known in the space community, as I am sure he is to many of you. He is also a superb technical manager of national, visible state-of-the-art enterprises with a very low tolerance for failure.

He and I both agree that one of his earliest responsibilities is to develop congressional understanding that our defensive technology development is a responsible part and parcel of overall arms control strategy. I would expect him to also develop his program along several technical criteria essential for any realistic strategic defense; that is, such a defense would not itself be vulnerable to sudden destruction. Its technical feasibility would be demonstrated

before any decision is made to proceed beyond research and development. It need not necessarily be nuclear. It would be relatively insensitive to simple proliferation or MIRV-related decoying. It would not depend on any one silver bullet. And, finally, its cost would be comparable to offensive countermeasures or attempts to rebuild the Soviet ICBM fleet.

I see these characteristics as our immediate goals, and I have listed them in what I think is their approximate order or urgency. I do not believe it is important now to discuss specific technologies; that time will certainly come. That is what the first phase of the program is all about. It is more important now that we demonstrate to decisionmakers, such as yourselves and the Americans who will pay the bills, that we know what we are about, not so much that we know exactly which widget will go where.

But in order to leave our successors any options at all, we cannot tie our hands now. While I see absolutely no need to violate any provisions on existing treaties while we investigate these options, I am very leery of entangling ourselves in further constraints until we know more. Then I want a comprehensive, broadly thoughtout, planned course of action which is not blocked by a previous patchwork of obligations whose provisions have been implemented independent of each other.

I would simply ask the Congress, Mr. Chairman, not to resolve itself too early to such limited sets of options that it removes all future options from the next generation. Rather, when that future generation's leaders have the information they need for a decision, we want commitment to positive actions on the part of both the United States and the Soviet Union, actions that are mutually verifiable, self-stabilizing, resistent to the consequences should cheating occur, and put us on the road to build-down.

Thank you very much.

Senator PRESSLER. Thank you very much.

Next I shall call on Lt. Gen. James Abrahamson. Again, I would ask if we could limit our statements to 10 minutes and summarize, we would much appreciate it.

STATEMENT OF LT. GEN. JAMES A. ABRAHAMSON, DIRECTOR, STRATEGIC DEFENSE INITIATIVE ORGANIZATION, ACCOMPANIED BY JOHN GARDNER

General ABRAHAMSON. Sir, I will follow that instruction. However, I do have with me some supporting and very effective people who have been conducting and working on this program for a very long period of time.

Senator PRESSLER. Would you pull that microphone a little closer? I am getting some signals that people cannot hear. Thank you.

General ABRAHAMSON. On my left is Dr. Cooper, the Director of DARPA [Defense Advanced Research Projects Agency], who has been a pioneer in this effort for a long period of time. On Dr. Keyworth's right is Mr. Richard Perle who has led many of the policy investigations and discussions in this area, and I also have included Mr. John Gardner, who is an expert in several of the directed energy areas as well as in survivability.

I do have an extensive statement on the technologies and on our management of the program. I will offer this for the record. I would, however, like to read a very short portion of what we are about, since Dr. Keyworth, I think, laid the foundation of the task that we are about in an excellent way.

Secretary Weinberger recently selected me to be the program's Director. I began acting in this capacity on April 16, and of course I am very pleased to be here today to testify before this committee.

We are frequently asked whether the purpose of the Strategic Defense Initiative is to defend people or military forces. That was your question, sir. Accomplishment of both missions is essential to the ultimate goal, which is to provide security for the people of the United States and—and I would like to underscore—our allies.

The immediate objective, however, is to conduct research on those technologies which might enable the development of defensive systems capable of intercepting ballistic missiles after they have been launched and preventing them from hitting their targets.

Once proven, these technologies could be used for the design and development of an appropriate system of defenses. The highly effective defenses that we envision have three attributes which we believe would contribute to that ultimate objective. First and foremost, an effective defense against ballistic missiles would improve stability and reduce the likelihood of war by eliminating the military utility of a preemptive nuclear strike. Second, in the unlikely event, whether planned or accidental, that nuclear weapons would be used in the face of effective ballistic missile and other defenses, such defenses would save lives and limit damage. Third, by reducing the value of offensive nuclear forces, both military and economic incentives would be created for negotiated offensive force reductions.

I think Dr. Keyworth made each of those points in much more detail.

I would like to make a special point of the fact that our research is focusing on defenses against ballistic missiles of all ranges, including tactical and theater range systems, as well as ICBM's and SLBM's.

In this morning's paper, we were quoted as widening the program. That really is not true. Administration witnesses have for some time tried to articulate that it is, in fact, defense against the nuclear ballistic missile with the characteristics that it has of rising for many hundreds of miles above the atmosphere and therefore systems that we may develop or may be effective or prove to be effective against those kinds of nuclear ballistic missiles would be effective, not only for intercontinental range missiles, but also for the shorter-range theater types of missiles themselves.

We are not seeking only to build defenses for the United States. As Secretary Weinberger has indicated, our concept of an effective defense is one which protects our allies as well as the United States.

Finally, I must underscore Soviet efforts in the ballistic missile defense area. The evidence of massive Soviet investments and programs is overwhelming. Were they to deploy the fruits of their programs unilaterally, the consequences to our national security

would be exceedingly grave. However, a U.S. program capable of responding to Soviet deployment could lead to a safer world, with deterrence increasingly based on effective defenses for all sides.

Now, that is truly the objective. There is a description of the technologies of the systems, but I think that Dr. Keyworth's explanation is a superb base on which any questions you might like to ask would be available.

However, Dr. Cooper, would you like to comment on relationship to the ASAT?

[General Abrahamson's prepared statement follows:]



STATEMENT ON

THE PRESIDENT'S STRATEGIC DEFENSE INITIATIVE

BY

LIEUTENANT GENERAL JAMES A. ABRAHAMSON
DIRECTOR,
STRATEGIC DEFENSE INITIATIVE ORGANIZATION

BEFORE THE

COMMITTEE ON FOREIGN RELATIONS

UNITED STATES SENATE

98TH CONGRESS, SECOND SESSION

APRIL 25, 1984

THE PRESIDENT'S STRATEGIC DEFENSE INITIATIVE (SDI)

INTRODUCTION

In a speech to the American people a year ago, President Reagan offered the hope of a world made safe from the threat of ballistic missiles. More specifically, he stated, "Our ultimate goal ... (is) eliminating the threat posed by strategic nuclear missiles," and "our only purpose ... is to search for ways to reduce the danger of nuclear war."

President Reagan based this goal on recent technological advances which, he believes, offer us, for the first time in history, the opportunity to strengthen deterrence through effective defenses, rather than only through the threat of retaliation. He is determined that we exploit fully this opportunity. I am convinced he is right.

Secretary Weinberger recently selected me to be the program's director. I began acting in this capacity on April 16, and I am pleased to be here today to testify before this committee. I would like to give you a general overview of the program, including its purpose, the funds we are requesting, and a summary description of the research and technology efforts we propose to pursue.

THE GOAL OF THE SDI

We are frequently asked whether the purpose of the Strategic Defense Initiative (SDI) is to defend people or military forces. Accomplishment of both missions is essential to the ultimate goal, which is to provide security for the people of the United States and our allies. The immediate objective is to conduct research on those technologies which might enable the development of defensive systems capable of intercepting ballistic missiles after they have been launched and preventing them from hitting their targets.

Once proven, these technologies could be used for the design and development of an appropriate system of defenses. The highly effective defenses that we envision have three attributes which, we believe, would contribute to the ultimate objective. First and foremost, an effective defense against ballistic missiles would improve stability and reduce the likelihood of war by eliminating the military utility of a preemptive nuclear strike. Second, in the unlikely event--whether planned or accidental--that nuclear weapons would be used in the face of effective ballistic missile and other defenses, such defenses would save

lives and limit damage. Third, by reducing the value of offensive nuclear forces, both military and economic incentives would be created for negotiated offensive force reductions.

I want to make a special point of the fact that our research is focusing on defenses against ballistic missiles of all ranges, including tactical and theater range systems as well as ICBM's and SLBM's. We are not seeking only to build defenses for the United States. As Secretary Weinberger has indicated, our concept of an "effective" defense is one which protects our Allies as well as the United States.

I must underscore Soviet efforts in the ballistic missile defense area. The evidence of massive Soviet investments and programs is overwhelming. Were they to deploy the fruits of their programs unilaterally, the consequences to our national security would be exceedingly grave. However, a U.S. program capable of responding to Soviet deployments could lead to a safer world, with deterrence increasingly based on effective defenses for all sides.

FUNDING

We plan an aggressive, adequately funded program to pursue the relevant technologies at the maximum reasonable rate. For fiscal year 1985 we are requesting approximately $2 billion (total for DoD and DoE). We anticipate that during the fiscal year 1986-89 period, approximately $24 billion will be required.

The program is not a "new start" in the usual sense. Substantially all of the relevant technologies have been funded in previous years, but not all have been specifically related to defending against ballistic missiles. To implement the President's Strategic Defense Initiative, we have focused these previously existing related research efforts into a single program, and augmented the previously planned level of DoD funding for fiscal year 1985, $1,527 million, by $250 million, for a total request of $1,777 million. The DoD request is for 71% real growth in relevant technologies from fiscal year 84 to 85, and 16% relative to pre-SDI plans for fiscal year 1985. Part of the Initiative includes technologies involving nuclear devices, which are developed by the Department of Energy. Their work in direct support of this initiative in fiscal year 1985 is a portion of their nuclear research, development, and test funding. It is estimated at $210 million (It is not a separate, specific line item.) for a total program of $2 billion.

The DoD portion of the program has been divided into five technical areas, and a new program element has been established for each of them. These program elements are:

1. Surveillance, acquisition, and tracking,

2. Directed energy weapons,

3. Kinetic energy weapons,

4. Systems analyses and battle management, and

5. Support programs.

These are Defense level program elements. Their descriptions are found in the Defense Agencies book of RDT&E descriptive summaries.

THE CONCEPT OF DEFENSE

The flight of a ballistic missile can be considered in four phases. The first is the boost phase, in which the first and second stage rocket engines of the missile are burning. They produce an intense and unique infrared signature. In the second, or post-boost phase, the bus separates from the main engines, and the multiple warheads are deployed from the bus, along with any penetration aids such as decoys and chaff. In the third, or mid-course phase, the multiple warheads and penetration aids travel on ballistic trajectories through space, above the earth's atmosphere. In the fourth, terminal phase, the warheads and penetration aids reenter the earth's atmosphere, where they are affected by atmospheric conditions.

Our program seeks to explore technologies enabling the engagement of attacking missiles in all four phases of their flight. This would require a number of capabilities, including global, full-time surveillance to warn of an attack. There is leverage in engaging the missiles in the boost phase, because the multiple warheads and penetration aids have not yet been been deployed. After deployment, we must be able to discriminate warheads from decoys, so we can target only the real threats. We must be prepared for the attacking warheads to be salvage fuzed; therefore, our terminal defenses must engage them at as high an altitude as possible. And in addition to the individual engagement capabilities, we must have a survivable battle management system capable of efficient, global control.

The technologies for the terminal defenses are also likely to be applicable to defense against the shorter range nuclear ballistic missiles, such as submarine launched ballistic missiles and theater range ballistic missiles, which may not have trajectories high enough to permit their attack with exoatmospheric systems, and which have short times-of-flight. Such technologies are important for defense of our allies.

THE TECHNOLOGIES

Surveillance, acquisition, and tracking:

Surveillance, acquisition, tracking and kill assessment (SATKA) includes sensing of information for initiation of the defense engagement and for battle management and assessment of the status of forces before and during a defense engagement against nuclear ballistic missiles. It also includes signal processing and data processing for discrimination of threatening reentry vehicles from other objects and backgrounds. A crucial philosophy of design is that surveillance and acquisition should be autonomous in each phase of the engagement, but that tracking and kill assessment should be consultative through battle management. These requirements are necessary so that the contributions to leakage from missed detections remain independent to insure very high quality tracking and kill assessment.

The goal of this program is to develop and demonstrate the capabilities needed to detect, track, and discriminate objects in all phases of the ballistic missile trajectory. The technology developed under this program is quite complex, and any eventual system must operate reliably even in the presence of disturbances caused by nuclear weapons effects or direct enemy attack.

This program has several component technology development programs which culminate in hardware demonstrations. A focused effort to study the observables during each phase is the first major element of the program. Optical, infrared, and radar signatures of reentry vehicles and penetration aids will be measured. The new techniques of radar imaging represent another element. Similarly, optical imaging, using lasers rather than radar beams, will be pursued. Finally, a substantial effort is included to develop cooled infrared sensors and near real-time signal processing.

The technology programs outlined above will lead to a series of hardware demonstrations. Four key demonstrations have been identified at this time, with the possibility of more in the 1990s as technology progresses. One demonstration will be an advanced boost-phase detection and tracking system. Another major demonstration is designed to track and discriminate attacking objects in mid-course using advanced Long Wavelength Infrared (LWIR) sensors. The ability of airborne infrared sensors to identify and track reentering objects will be demonstrated in the Army's Airborne Optical System (AOS) development program. Ground radar imaging and tracking demonstrations will continue as part of the Army's terminal and midcourse defense programs. As other technologies mature, such as radar and optical imaging, new demonstrations will be conducted. As these demonstrations are completed, we will have obtained the technical information required to decide whether defensive systems of the necessary capability can be built, considering this key element of the defense design.

Directed Energy Weapons:

This program pursues four basic concepts identified as potentially capable of meeting a responsive threat--space-based lasers, ground-based lasers, space-based particle beams, and nuclear driven directed energy weapons. It also provides for establishment of the National Tri-Service Laser Test Range at White Sands Missile Range, NM. The basic technical thrusts include beam generators (lasers and particle accelerators), beam control, large optics, and acquisition, tracking and pointing. Our request includes funds to search for technological opportunities for new and innovative capabilities.

The goal of the directed energy technology program is to bring the most promising concepts for boost and post-boost phase intercept to an equivalent technical maturity in the early 1990's. At that point we expect to be able to demonstrate a readiness for technology validation in system level demonstrations of the concepts selected to move into that phase. To achieve that goal we plan to demonstrate the feasibility of the leading candidate beam generators by the mid 1980's and their scalability to weapon performance levels in the late 1980's or early 1990's. In beam control we will demonstrate by the end of the decade a capability to control wavefront errors, maintain beam alignment within the system, compensate for atmospheric effects; and provide the components necessary to transmit and control the high intensity beams. In large optics, we plan by the 1990's to demonstrate several approaches for providing the large diameter ground and space-based optics required for most directed energy concepts and all surveillance systems employing optical and electro-optical sensors. In our acquisition, tracking and pointing efforts, we envision in-space tests that verify our capability to point with the necessary precision, to acquire and track targets of interest, and to provide early experiments in imaging and designation. Finally, we are considering integrated technology experiments to show that we can integrate the weapon subsystems with requisite efficiency. With these demonstrations completed we will have provided the basis for a decision whether we are ready to move into the more complex system level demonstrations required in the technology validation phase of R&D.

Kinetic Energy Weapons:

Kinetic energy weapons include interceptor missiles and hypervelocity gun systems. The primary roles for these weapons include (1) midcourse engagement of reentry vehicles not destroyed during boost or post-boost phases, and of post-boost vehicles that have not dispensed all of their RV's, (2) terminal (i.e. endoatmospheric) engagement of RV's not destroyed during the previous phases of their flight, (3) space platform defense against threats not vulnerable to directed energy weapons, and (4) boost-phase engagement of short time-of-flight, short range submarine launched ballistic missiles. Additional roles for these weapons include (1) boost phase intercept from space-based platforms, and (2) midcourse engagement from space-based platforms. The kinetic

energy weapons will rely on nonnuclear kill mechanisms to destroy the intended target. The key technologies required to develop these weapons include (1) fire control, (2) guidance and control, (3) warheads and fuzing for guided projectiles capable of being launched by missiles or hypervelocity guns, (4) hypervelocity launchers, (5) and high performance interceptor missiles.

The goals of the kinetic energy weapons program are: (1) expansion of the technology data base to support the development of improved and advanced weapons and (2) development and flight demonstration of kinetic energy weapons which are designed to satisfy the SDI mission needs outlined above. Technology programs are planned for endoatmospheric and exoatmospheric interceptor designs, a hypervelocity launcher design, and the systems engineering and analysis required to integrate the various advanced subsystems and components into effective system constructs. Investigations will also be undertaken in novel and advanced techniques which have the potential for a high payoff in performance and/or cost effectiveness in the design of these weapons systems. Hardware development and flight test demonstration of a number of kinetic energy weapons system designs will also be undertaken as part of this program.

Systems Analyses and Battle Management:

This program has been divided into two technology projects. The Battle Management/Command, Control, and Communications technology project will develop the technologies necessary to allow eventual implementation of a highly responsive, ultra reliable, survivable, endurable and cost effective BM/C^3 system for a low-leakage defense system. This BM/C^3 system is expected to be quite complex and must operate reliably even in the presence of disturbances caused by nuclear effects or direct enemy attacks. This program seeks to (1) develop the tools, methods, and components necessary for development of the BM/C^3 system, and (2) quantify the risk and cost of achieving such a BM/C^3 system to control the complex, multi-tiered SDI system. The systems analyses project will provide overall SDI systems guidance to weapons, sensors, C^3, and supporting technologies. Tasks include threat analyses, mission analyses, concept formulation, system conceptual design, and subsystem requirements definition, system evaluation, and technology assessment for all levels of a multi-tiered, low-leakage system.

One of our early tasks will be to conduct a "sanity check" on the defense responsibilities allocated to the various phases of the multi-tiered system by the Defensive Technology Study. Even though we know that many of our weapons and sensor concepts will require orders of magnitude performance improvements to accomplish the President's defense objectives, we also know that effective overall system guidance will efficiently focus these technology efforts and help us avoid "gold plating" and "blind alleys."

Obviously, if such a complex defense system were deployed, it would require positive control of its operations. We have to assure that we can turn the system on when it is needed and assure that it is safe when not needed. Just as importantly, the system must not be regarded as a "paper tiger" by the Soviets if it is to serve as an effective deterrent to nuclear war. Therefore, its credibility must be based on a demonstrated capability to manage the surveillance, tracking and intercept actions over the multi-tiers of this complex system. The information processing capability, specifically the development of complex software packges, necessary to associate outputs from multiple sensors, performing discrimination and designation, and "birth to death" tracking, plus kill assessment is expected to stress software development technology.

Our immediate need is for effective approaches and tools for achieving high performance processors and software, and responsive communications networks that provide high reliability and fault tolerance. Evaluation and demonstration of this complex defense system and its C^3 will largely depend upon simulation. Therefore, development of effective modeling and simulation tools will also be an early priority endeavor.

Support Programs:

This program element funds a collection of essential efforts designed to provide timely answers to a variety of critical SDI support related questions. The Defensive Technologies Study (the report of the Fletcher panel) identified two areas that should receive priority attention in the SDI program.

First, for each weapon concept under consideration, we must develop the ability to scientifically predict the minimum energy that will be required, in a variety of engagement scenarios, to kill unhardened, retrofit hardened, and responsively hardened Soviet systems. These data will have a large effect on our choice of candidate system concepts. The feasibility of SDI may well hinge on the results of these efforts. The Lethality and Target Hardening project of the Support Programs effort is structured to provide these data.

Second, the ability of any deployed ballistic missile defense system to survive in the face of dedicated attack and to continue to function effectively must be established. The concepts, technologies and tactics necessary to insure continued system effectiveness will be defined and developed under the Survivability element of Support Programs. The output from this effort will be fed into all other elements of the SDI--particularly into the Systems Concepts and Analyses efforts.

Additionally, support programs will fund development of the technologies necessary for improved space logistics capabilities. These

include the advanced orbital transfer vehicle capabilities that SDI will likely require. We will also evaluate the technical feasibility and cost effectiveness of using extraterrestrial materials for certain SDI applications.

Many SDI system elements (weapons, sensors, etc.) will require large amounts of electrical power. The Power and Power Conversion element of support programs will fund concept definition and technology development for multimegawatt power systems. This effort will fully exploit the technologies being developed in the joint NASA, DoE, DARPA SP-100 program. Both nuclear and non-nuclear systems and technologies will be considered.

The Department of Energy's Contribution to the SDI program:

Although funded separately, the Department of Energy (DoE) program is integral to the overall Strategic Defense Initiative program. DoE funded efforts include concepts for nuclear driven x-ray lasers, survivability and lethality, and support subsystems. Other efforts, such as space-based neutral particle beam technology, are being performed by the DoE laboratories with DoD funds. A memorandum of understanding, to be signed by the Secretaries of Defense and Energy, is presently in coordination. It will establish specific relationships between the elements of DoD and DoE engaged in planning and execution of the SDI. In accord with current policy, the DoE will have primary responsibility for nuclear source development, and the DoD for applications, target acquisition, beam control, and pointing/tracking. The DoE laboratories have unique facilities and capabilities to address many aspects of these difficult problems.

MANAGEMENT

The Defensive Technologies Study (the Fletcher panel report) emphasized the importance of strong central management for the SDI. The Department of Defense is absolutely committed to this principal and I would like to outline how we are following this guidance.

We have established a Strategic Defense Initiative Organization to manage the SDI program. The Secretary of Defense intends that the director will report directly to him and will have overall responsibility for managing the program and reporting on its progress. In the next few weeks we will organize a highly centralized dedicated staff to proceed with this important effort.

We will also work to establish relationships with other agencies and organizations, both within and outside the Department of Defense, to facilitate progress on the program. The Senior Interagency Group-Defense Policy (SIG-DP) has overseen all efforts of the SDI to date.

This group, chaired by the Deputy Secretary of Defense and including senior representatives from all US national security organizations, will continue to provide top level coordination and review of both our technology work and the political and military implications of strategic defense for the US and its allies. An SDI Executive Committee (EXCOM) consisting of the senior officers of the Services, Military Departments, Defense Agencies and components of the Office of the Secretary of Defense, and also chaired by the Deputy Secretary of Defense, has coordinated internal DoD efforts on the SDI. The EXCOM will continue in this capacity. In order to execute the program we will establish, in consultation with the Services and Defense Agencies, constructive relationships with those Service and Agency staffs. The charter further authorizes the establishment of a special SDI Advisory Panel consisting of scientific, industrial, and academic experts who will assist us and provide important independent assessment of our plans and research efforts. We will work with the Joint Chiefs of Staff and the Under Secretary of Defense for Policy in establishing mechanisms for assessing the strategy and policy implications of defensive capabilities. We will also work closely with the Under Secretary of Defense for Research and Engineering to coordinate SDI programs with other related DoD programs to avoid duplication of effort. Since a significant portion of the SDI will be conducted by the Department of Energy, we have a formal memorandum of understanding now in coordination to cover that Department's SDI work.

To carry the SDI through for the long-term there are three fundamental authorities which the director will have:

1. Establishment of streamlined channels of communication and direction with the Services and Agencies which will be conducting the work. Each Service and Agency will be asked to designate a single office of responsibility for its portion of the SDI. This will facilitate prompt response on the program.

2. Responsibility to the Secretary of Defense for the SDI' planning, programming and budgeting system.

3. In consultation with the Service and Agency staffs, the Director will designate lead organizations, responsible for execution of the SDI projects and tasks. These projects and tasks have been centralized in five Program Elements which will be managed by the SDI staff. He will initiate reprogramings as required. We will seek class Determination and Findings authority for the SDI, as well as simplified procedures for rapid and creative means of achieving program objectives.

The most important aspect of our management structure is the availability of top-notch dedicated people. I am already singularly impressed with the people with whom I will be working, both within the

Office of the Secretary of Defense and within the Services and Agencies. I have every reason for confidence that these people will meet the challenge the President has set.

CONCLUSION

In conclusion, I am pleased to have the opportunity to contribute to making the President's vision a reality. He has outlined a strategy of hope for people all over the world and for future generations. We need your help and commitment to undertake this noble challenge. We are dedicated to a program that will provide our future leaders with options to enhance deterrence and stability by eliminating the threatening role that ballistic missiles play in our world. The mere promise of such options may remove the pall of fear and anxiety that overshadows our young and provide them with the confidence that their future need not be dominated by the overriding fear of nuclear destruction.

STATEMENT OF DR. ROBERT S. COOPER, DIRECTOR, DEFENSE ADVANCED RESEARCH PROJECTS AGENCY

Dr. COOPER. In your letter requesting that we come today to testify, you asked for a summary of the current status of the ASAT program, and I have prepared testimony which I would like to insert into the record which does summarize the current status. But perhaps I could just summarize briefly some of the contents of that testimony.

The President has articulated in the past the need for a U.S. ASAT capability, and a program which was started in the latter part of the 1970's to accomplish that is well underway. Certain low-altitude Soviet satellites represent a serious threat to our land, sea, and aerospace forces, and we must have the capability to engage these systems in the event of conflict.

The baseline air-launched minature vehicle, ASAT, is now in flight test. The first test was highly successful and demonstrated booster and guidance performance. There is every indication that the system will be capable of meeting fully its original performance specification and can be made even more capable as the Soviet threat matures or in the event the Soviets attempt to countermeasure the system.

Although we have conducted studies, we have no current plans to extend the performance of this system to higher altitudes. We are conducting basic research on directed energy technologies that one day may have ASAT applications. Some of these technologies are being developed within the context of the strategic defense research program, which Jay and Jim have both talked about.

Other multiuse technologies, such as surveillance and computer science, also may play key roles in advanced ASAT systems of the future. All of our activity in this area is completely consistent with our policy on arms control.

That policy, succinctly stated, is that the United States will consider verifiable and equitable arms control measures that would ban or otherwise limit testing and deployment of specific weapons

systems, should these measures be compatible with U.S. national security.

Now, the issue in the ASAT program is what is in the interest of U.S. national security? And in the particular case of the ASAT program, the ASAT is specifically aimed at surveillance systems which can be used for real-time targeting of our forces in the case of a conventional or nuclear conflict with the Soviet Union. That capability is an official military requirement, and it is even a good idea.

We would solicit your strong support to complete the ASAT program. It is not, as many have indicated, a tens of billions of dollars enterprise. The R&D program we estimate will cost about $1.35 billion to run out. We expect to invest about $2.5 billion in the procurement of the actual ASAT interceptors themselves and all of the ancillary equipment, and we expect that only $39 million of military construction funding will be required for that program, for a total of about $4¼ billion, for a capability which will protect our tactical forces in time of potential conflict with the Soviet Union.

Thank you very much, Mr. Chairman. That concludes my remarks.

Dr. KEYWORTH. Mr. Perle.

[Dr. Cooper's prepared statement follows:]

PREPARED STATEMENT OF DR. ROBERT S. COOPER

Mr. Chairman and members of the committee, I am pleased to have this opportunity to appear before you this morning to address the U.S. ASAT program.

The President outlined the need for an ASAT system in his National Space Policy Statement of July 1982: "The primary purposes of a United States ASAT capability are to deter threats to space systems of the United States and its allies and, within such limits imposed by international law, to deny any adversary the use of space-based system that provide support to hostile military forces."

For United States and allied security, the United States must continue its efforts to protect against threatening satellites. ASAT capabilities complement other measures that could be used throughout a conflict. To do otherwise would undermine both conventional and nuclear deterrence.

The baseline United States ASAT program is focused explicitly on those Soviet satellites which threaten United States and allied terrestrial interests in time of war. All of these Soviet satellites operate at low altitude. While the U.S. miniature vehicle ASAT system will be able, when operational, to attack only a portion of all Soviet satellites, it will be able to seriously degrade Soviet reconnaissance and tactical targeting capability and thus serve U.S. deterrence objectives. It cannot and need not attack Soviet early warning or communications and navigation satellites at high altitudes.

The U.S. miniature vehicle ASAT consists of three segments: a surveillance system, a mission control center, and the ASAT weapon system. The surveillance system provides the orbital tracking data necessary to target Soviet satellites. The space detection and tracking system, an existing world-wide network of radar and optical sensors is used for this purpose. The data from these sensors are sent to NORAD Cheyenne Mountain Complex for compilation and analysis. Using this data, the Mission Control Center, also located in Cheyenne Mountain, generates intercept profiles for the weapon system. The weapon system, presently under development consists of an infrared-guided nonnuclear miniature vehicle mounted on a two-stage SRAM/ALTAIR booster. This is carried aloft and launched from a specially modified F-15 aircraft. The MV will be capable of attacking satellites in low altitude orbits. It is to be deployed at two bases: Langley AFB, Va. on the east coast and McChord AFB, Washington on the west coast.

The main activity of the ASAT development program at the current time is the test program. Captive carry flight tests, to verify compatibility between the F-15 aircraft and the missile, and to test the prototype mission control, began in December 1982. We have completed 17 such tests to date. In January 1984, we had the first test of an actual ASAT missile launch from an F-15. The objectives were to test the ejection of the missile from the aircraft, the propulsion and guidance systems of the

missile and the miniature vehicle dispenser system. An inert miniature vehicle simulator was used in this test. All test objectives were met.

The objective of the next test will be to test the acquisition and tracking capability of the miniature vehicle. The third test scheduled for late this year, subject to satisfying the conditions of the so-called Tsongas amendment, will be the first one against an object in space—an instrumented test vehicle.

The most recent estimate for the cost of the air-launched miniature ASAT is $1.35 billion for development, $2.50 billion for procurement, and $39 million for milcon. Approximately $1.00 billion will have been spent in FY84 and prior years.

The Air Force is funding, at a very low level (about $500 thousand in FY85), studies to examine concepts for improvements to the current ASAT system. Other promising technologies which might have ASAT applications for the future, such as ground-based lasers, are also being investigated in our basic research program. We have no ongoing program to select a specific follow-on ASAT system with a higher altitude capability.

STATEMENT OF HON. RICHARD N. PERLE, ASSISTANT SECRETARY OF DEFENSE FOR INTERNATIONAL SECURITY POLICY

Mr. PERLE. Mr. Chairman, I am grateful for this opportunity to appear before this committee to participate in these discussions on antisatellite arms control and the U.S. ASAT program.

On March 31 of this year, the President issued his report on U.S. Policy on ASAT Arms Control. It is a comprehensive report that provides a large amount of data to support an informed debate on this issue. It also sets forth a policy which I hope you will be persuaded is in the best interest of the United States and its satellites.

The report concludes—and I quote—that: "No arrangement or agreements beyond those already governing military activities in outer space have been found to date that are judged to be in the overall interest of the United States and its allies."

However, the report also notes that, guided by the criteria contained in the President's space policy announced on July 4, 1982—and again I quote: "The U.S. has been studying a range of possible options for space arms control with a view to possible negotiations with the Soviet Union and other nations if such negotiations would serve U.S. interests."

The reasons why the administration has been unable to recommend ASAT arms control measures include the unverifiability of proposed measures, the difficulty of defining ASAT systems in a comprehensive way that would effectively limit threats to the United States and allied satellites, and the threats posed by Soviet targeting and reconnaissance satellites that undermine conventional and nuclear deterrence. Each of these factors is discussed at length in the President's report, so I will not go into great detail about them here and now.

I would like, however, to say just a few words about verification, since it is sometimes argued that concern about verification is simply a pretext for avoiding arms control agreements that are in fact opposed on other grounds. I can assure you that our concern about the verifiability of an ASAT arms control agreement is genuine.

As the committee is aware, we are talking about the survivability of a relatively few but vital U.S. satellites. From this point of view, an unverifiable treaty is far worse than no treaty at all. Under an insufficiently verifiable treaty, the Soviets would be able

to develop and maintain a covert capability to attack those vital satellites.

For example, a small covert supply of ASAT interceptors would be enough to do a disproportionate amount of damage to our space assets, since these could be launched using boosters that the Soviets could legitimately maintain for other space programs.

Similarly, given the wide range of space systems, including some nonweapon systems that could have an ASAT capability, the opportunities exist to develop an ASAT capability in the guise of some thing else. Even if the tests of this capability were detected, there would be considerable, perhaps insurmountable, difficulty in distinguishing the ASAT capability from an innocuous civil or military capability which it resembled.

We, on the other hand, would be most likely to relax our unilateral efforts to make our satellites more survivable, and would of course find that funding for these efforts were more difficult to obtain in the absence of hard evidence of Soviet cheating.

Furthermore, we would not be able to deter a Soviet attack on our satellites during a crisis, since we would not have developed an operational ASAT capability of our own.

For this reason, I think it is those who most worry about the survivability of our satellites who should be most wary of an insufficiently verifiable ASAT agreements. I might add that these judgments come against the background of our report issued by the President at the end of last year in which he has found, after extensive study, that the Soviets are presently violating the most important arms control agreements that exist between this country and the Soviet Union.

I was struck that in the opening remarks that preceded the testimony in this hearing, not a word was said about the impact on the confidence that we can have in low verifiable or marginally verifiable or unverifiable arrangements of a record of systematic violations of existing agreements.

In addition to the problems associated with arms control in this area, I believe that we must avoid unilateral actions that would undercut our national security. In particular, the Congress should reject measures that would have the effect of preventing the United States from acquiring an ASAT capability while leaving the Soviets in full possession of theirs.

I wish to emphasize that the Soviet Union presently has an operational ASAT capability and the effect of most of the proposed legislation that I have seen would be to prevent the United States from proceeding to develop a countering capability of our own, thus leaving the Soviets with a monopoly of this capability and leaving us without the capability to respond in kind in the event that the Soviets in wartime were to launch an attack on our critical satellites in space.

Mr. Chairman, my prepared remarks have been brief, because I think that the President's report speaks for itself. Like the others present, I would be happy to answer any questions you may have.

I would only like to make one comment in response to comments made earlier in the opening statements. I believe it was Senator Pressler who said we would all be delighted if we did not have MIRV's [multiple independently targeted reentry vehicles] today.

The implication of the way that was put is that the Soviets would have refrained from developing MIRV's if the United States had refrained from developing MIRV's. I observed in reading remarks made by Senator Pressler on the floor of the Senate, that he has described the situation in the late 1960's as one in which the United States refused to consider arms control as a way of dealing with the evolution of MIRV technology.

I wish to set the record straight on that point. Under the Nixon administration, in the early days of the SALT I negotiations, we did in fact propose a MIRV ban to the Soviet Union. The Soviets rejected our proposal because it was tied unavoidably to a requirement for onsite inspection. As we had no sure means of determining whether a missile contained one or more warheads, I think the historical record on this is clear. We made the effort, and it was unsuccessful.

I would be delighted if the Soviets did not have MIRV's today, but I fail to see how a unilateral decision by the United States not to proceed with MIRV would have produced a similar decision on the part of the Soviet Union, and indeed all of our historic experience suggests that the Soviets will deploy any weapon of which they are capable independently of the attitude of the United States. I cannot think of a better example of that than the ASAT weapon that the Soviets possess today, a weapon they deployed long before the United States even considered a program of its own, and that they have maintained operational for a number of years.

If I may make one further comment, Senator Tsongas has expressed the prediction that history will not treat this administration kindly, because, as I understood it, there has been no progress on arms control. I find that an astonishing statement in light of the fact that the failure to achieve progress on the principal arms control negotiations underway lies directly with the party that has walked out of those negotiations.

It is, after all, the Soviet Union that has walked out of the negotiations on intermediate nuclear forces. It is the Soviet Union that has walked out of the START negotiations, and it seems to me any fair evaluation of the responsibility of this administration, compared to the responsibility of what has now become three Soviet administrations during the period that we have been negotiating, would have to focus on the question of whether the proposals made by the United States at the INF talks, at the START talks, have been fair and equitable proposals that provide a reasonable basis for negotiation, because it seems to me that unless you can show that the proposals put forward by the American side have not been an adequate basis for negotiation—and we would be delighted to hear suggestions for other proposals that would bring us closer to a success—the otherwhelming fact remains that the Soviets have walked out of those negotiations and there is precious little we can do to advance toward progress on arms control when the other side won't come to the table.

Senator TSONGAS. Mr. Chairman, I would like to state for the record that the United States has negotiated and then not ratified three separate treaties that sit before this committee—the Peaceful

Nuclear Explosion [PNE], Threshold Test Ban [TTB], and SALT II Treaties.

The current administration and Mr. Perle were instrumental in making sure SALT II was never ratified. They are also refusing to even talk about ASAT's or "Star Wars." That is the historical record. I would hope that when that is looked at objectively, the record will be viewed as not as clearcut as has been suggested.

Thank you.

Senator PRESSLER. Also, let me say that I think you are referring to my statement on MIRV's that was in a Los Angeles Times op ed. I suggested that efforts to control MIRV's in the late 1960's would have better served U.S. interests. Again, at that time, we were told that this was the solution to our security problems and that this was going to give us a superiority that wouldn't be challenged. And once again, we are in a vulnerable position. Indeed, I believe the Scowcroft Commission agrees with this.

In any event, I want to get into some of my questions because I know some of my colleagues have to leave. First of all, in President Reagan's March 23 address, he called for a research and development effort to "give us the means to render these nuclear weapons impotent and obsolete." First, do you believe, in your professional judgment, that a complete defense against ICBM's is possible? Second, if some ICBM warheads could still get through, what value would such a defense have? Third, what would be the value of such a defense if cruise missiles and bombers could get through it anyway?

Anyone could respond to that.

General ABRAHAMSON. First of all, I think it is worthwhile to go back to the Fletcher Commission report itself. What the Fletcher Commission report outlined, again, a scientific effort to evaluate the feasibility of establishing such a system itself was a layered system. And the practicality of such a layered system does depend on a reasonable effectiveness at each element of the layer or at each layer. However, it is the sum of all of those layers that begins to offer the hope of such an effective system.

For example, if there were five layers, and each layer was only 85 percent effective, then about one one-hundredth of 1 percent of the missiles could—or the RV's—could get through.

I think the important thing is that we have before us a goal, a goal that is set out as a very difficult goal, but nonetheless one that we should keep in mind as we investigate each of these technologies. The President has done that. He has set out a clarion call, very similar, of course, to what President Kennedy set out just before Senator Glenn's initial flight, at a time when very few people believed that you could go to the moon. And, in fact, people were not even sure exactly how at that point. But, nonetheless, there was sufficient faith in the technology that America could produce, that President Kennedy set that goal for all of us and it was proven.

And I guess my experience as a technologist and as a manager with a long career in this effort is that we indeed can produce miracles. I think that is what the shuttle program has recently shown me, and I believe that American technical muscle can, over a long period of time, do precisely what has been laid out.

The immediate step, however, is to investigate what is the best way to proceed, a way that will be affordable, that certainly will increase stability at every step on the way, and one that future Presidents and future Congresses can debate and make a decision about implementation of each stage of it.

Senator TSONGAS. Mr. Chairman, may I ask for a repetition of the example that was used about the five layers and 85 percent effectiveness? Would you repeat that for the record?

General ABRAHAMSON. Yes, sir. Five layers of a defensive system might well include such a thing as a layer that could reach out and intercept a ballistic missile shortly after it rises off the pad, when it is indeed very vulnerable, if you can project your power that far.

It may also then include a layer at the point that the ballistic missile burns out, but before the time that it really separates into many MIRV'd systems and decoys that make it difficult. There could be one or two layers of midcourse and interception out of the atmosphere, and finally, a layer down near the terminal area, similar to what has been talked about before in terminal defenses, perhaps different technology involved.

If each of those layers were, as I indicated, 85 percent effective, very few warheads would be able to get through. And that is, in fact, the basis of that technology investigation.

Now, what the Fletcher Report is not is a specific suggestion of what system it is that we should build in order to achieve that goal. What it has laid out is a series of technical alternatives that need to be evaluated very carefully. Some of those, I am sure, will be effective; some, in the end, may not be effective.

So it is too early to firmly project and say at this point in time we know that we can do this. However, I think many of us with experience in what this country can produce do feel that that is a worthy goal to set out.

Senator TSONGAS. The number that you used was that if all five layers were 85 percent effective, what percent would get through?

General ABRAHAMSON. .01 is the statistical number, sir—one one-hundredth of 1 percent.

Senator PRESSLER. I shall ask just one more question, and then I will yield my time to members who have to leave.

Dr. Cooper, in September 1982, I believe you testified before this committee that proponents of space-based missile defenses "grossly underestimated" the time involved and the costs associated with these programs. Has your opinion changed?

Dr. COOPER. Not at all. As a matter of fact, I believe that over the past year, the work of the Fletcher Committee and the statements made by the President himself have shown that my judgments on that are held by a large fraction of both the technical and nontechnical community.

You have to realize that the proponents at that time were talking about having systems in space that were effective within 3 to 5 years. The President has said it may not be possible to create systems of this sort in this century. The Fletcher Committee said that we may be able to create options for ourselves to start development of systems in the 1990's. All of those statements, except for the very optimistic ones are consistent, I believe, with my testimony of last year.

Senator PRESSLER. I have some more questions, but I will yield to my colleagues. I do want to put three articles from the magazine Aviation Week and Space Technology which summarize the key conclusions of the Presidential study groups on strategic defense technology into the record. I will also place in the record two articles by Jeffrey Smith in Science which discuss the intergovernmental disputes that have arisen about the prospects and promise of strategic defense.

[The articles referred to follow:]

[From Aviation Week & Space Technology, Oct. 17, 1983]

PANEL URGES DEFENSE TECHNOLOGY ADVANCES

SENIOR INTERAGENCY GROUP ADVISES STRONG NUCLEAR MISSILE DEFENSIVE EFFORTS COUPLED WITH EARLY DEMONSTRATION PLANS

(By Clarence A. Robinson, Jr.)

WASHINGTON.—An Administration senior interagency group recommended to President Reagan late last week that the U.S. embark on early demonstrations of credible ballistic missile defense technologies to its allies and the Soviet Union.

In recommending a technology development plan to the President, the group, represented by Defense Secretary Caspar W. Weinberger and William P. Clark, assistant to the President for national security affairs, stressed the importance of showing the U.S. is determined to explore and has the competence to develop the required ballistic missile defense technology.

Parallel study

The interagency report melds a Defensive Technologies Study Team's report with a parallel strategy study conducted between June 1 and Oct. 1. It also presents to the President four funding levels for developing an effective ballistic missile defense system. Funding profiles from Fiscal 1985 through Fiscal 1989 range from $27 billion to $18 billion.

The Defensive Technologies Study Team was headed by James C. Fletcher, former administrator of the National Aeronautics and Space Administration. The parallel strategy group, known as the Future Security Strategy Study, called FS, was headed by Fred S. Hoffman, director, Pan Heuristics, a division of Research and Development Associates.

"With vigorous technology development programs, the potential for ballistic missile defense can be demonstrated by the early 1990s," the interagency report said. It also stressed that the development program will not impinge in the near term on the 1972 antiballistic missile treaty with the USSR.

Maximum flexibility

"Early development programs are configured to provide maximum flexibility and demonstrated capability within treaties, protocols, agreements and political constraints," the interagency report said.

The report said the nation should establish the resolve for a new strategy to defend against nuclear weapons attack.

It added that an advanced technology ballistic missile defense system for the U.S. and its allies will reduce the military effectiveness of a Soviet preemptive attack with nuclear-armed ballistic missiles. "By constraining or eliminating effective counterforce options, the utility of strategic and theater nuclear weapons are reduced and the threshold of nuclear war is raised. It undermines the confidence that an attack will succeed."

Early technology demonstrations planned by the interagency group include:

Underground tests at the Nevada nuclear test site leading toward the ability to scale the Lawrence Livermore Laboratory's X-ray laser to full military power, to control the laser beam spread, and simultaneously drive multiple lasers from a single power source.

Acqusition and tracking of reentry vehicles using long-wavelength infrared sensors and high-altitude aircraft. This also includes a separate demonstration of intercepting warheads within the atmosphere above 50,000 ft. and nonnuclear kill devices on interceptor missiles.

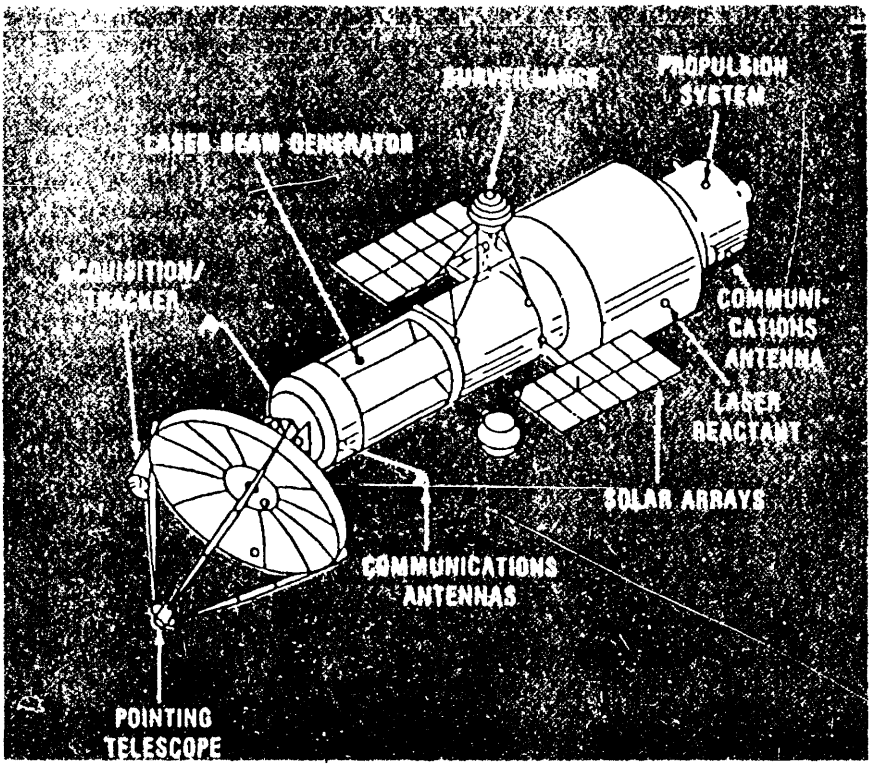
Ground-based short-wavelength lasers demonstrated against spacecraft in an antisatellite role.

Generic acquisition, tracking and pointing in space against intercontinental ballistic missiles in the boost phase.

Airborne optical system sensor and a low-cost homing interceptor. These technologies are key to terminal and midcourse intercepts in a multilayered system. This demonstration would be within three to five years following optical technology demonstration on interceptor missiles.

Proof of principle to acquire Soviet ballistic missiles and to track the booster, the first step in a high-technology payoff to use directed-energy weapons for boostphase intercepts.

The plan calls for parallel early technology demonstrations in a three-pronged program—infrared chemical lasers, ground-based excimer lasers and shorter wavelength chemical lasers. Tests could be conducted within a few years to determine the effectiveness of these devices against targets such as spacecraft.



A mid-infrared chemical laser spacecraft with 25-megawatt, 15-meter-dia. optics is depicted above for long-range, space-based antisatellite/defensive satellite missions and for boost and midcourse ballistic missile defense applications. The laser platform would weigh 100,000 kg., and have a run time of 100 sec. Scaling to 10^{23} watts/steerradian is possible. A multilayered ballistic missile defense system designed to permit only a 10% leakage of reentry vehicles in each layer, with overall leakage of 0.1%, is depicted in artist's drawing at right. Two surveillance and battle management platforms are positioned at an orbital altitude of 100,000 km.

A technology assessment conducted by the Defensive Technologies Study Team that formed part of the interagency report called for the following:

Chemical infrared space laser with a 2-megawatt beam generator feasibility demonstration in 1987. The device is scalable almost immediately to 10 megawatts because of breakthroughs in nozzle technology. Beam control of a 4-meter (13.12-ft.)

segmented optical system and mid-infrared beam control could be demonstrated in 1988.

A 1988 demonstration in acquisition, tracking and pointing could be conducted scalable to 50 nanoradians, with inertial reference technology to support 20-nanoradian pointing.

Free electron visible laser in space with a technical feasibility demonstration by 1986 for multimegawatt devices.

Free electron ground-to-space relay, with atmospheric compensation proof of concept by 1985.

Neutral particle beam technical feasibility demonstration/verification by 1985. The technical feasibility of beam sensing would be demonstrated by 1986.

X-ray laser technical feasibility demonstration to 10^{16} joules/steerradian by 1988.

The interagency group report calls for the Joint Chiefs of Staff to rapidly structure the program plan for ballistic missile defense technology for the Fiscal 1985 budget request to Congress, and for the chiefs to help structure the management approach to the program.

Bridging document

The interagency report to the President is also known as a bridging document since it seeks to blend technology and strategy studies with funding profiles and recommendations. The funding for a technology limited effort prepares for early deployment options. It would provide $2.6 billion to Fiscal 1985, a total of $27 billion in Fiscal 1985 through 1989. The total through deployment of single layer of a multilayered defense by the year 2000 would be $92-94 billion. A multilayer system would cost approximately $95 billion.

Without the early deployment option, the funding in Fiscal 1985 would remain the same, but funding in Fiscal 1985 through 1989 would be reduced to $26 billion. Intermediate funding, with no early deployment option and a later full system deployment would be $2.2 billion in Fiscal 1985, and a total of $20 billion from Fiscal 1985 through 1989.

A fiscally constrained program would cost $1.8 billion in Fiscal 1985, and a total of $18 billion in Fiscal 1985 through 1989.

The bridging document from the interagency group calls for centralized management of the ballistic missile defense program within the Defense Dept., "with a carefully chosen leader specifically oriented with interagency management authority similar to space intelligence efforts."

The interagency report, based on input from the Future Security Strategy Study, said advanced ballistic missile defense offers options to enhance deterrence and increase strategic stability. It adds: "Even prior to deployment, the demonstration of U.S. technology would strengthen military and negotiating stances, and options for immediate deployment would play a significant role in deterrence." It could be a hedge against early Soviet Union breakout of the Antiballistic Missile Treaty.

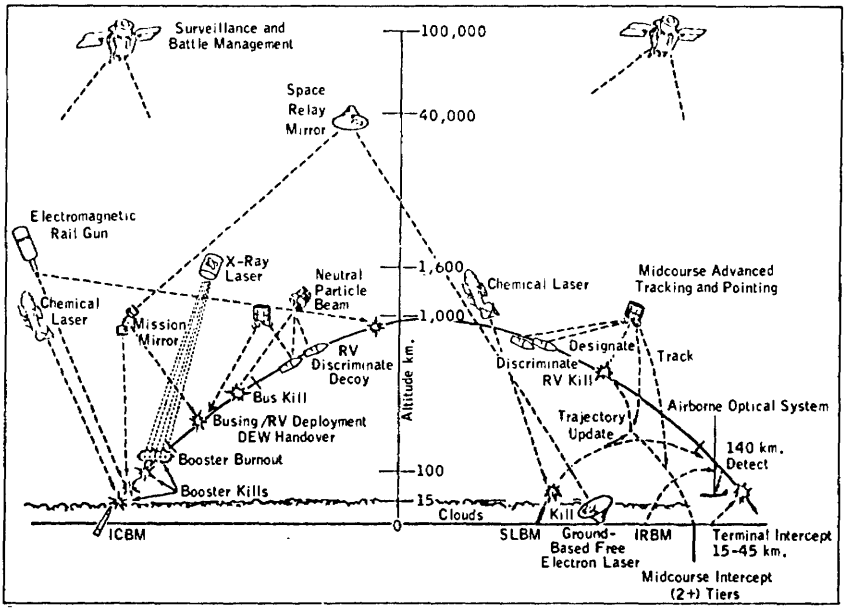
Over the next few years, the interagency report said technologies can move to higher confidence levels for critical ballistic missile defense decisions, while remaining within current treaty/agreement constraints. The program is therefore structured to identify long-range system payoffs and near-term progress demonstrations.

The assessment of the U.S. program presented to Reagan determined that while current technology levels can provide an effective counter to current Soviet intercontinental ballistic missiles in some important contingencies, the effectiveness of near-term deployment of systems based on present technologies alone could be eroded by Soviet technology advances and operational responses.

"The long-term technology, however, holds particular promise for highly effective and robust counters to Soviet countermeasures," the report said.

Early demonstrations of ballistic missile defensive technologies would help the U.S. in managing relations with the Soviet Union. But to aid in this, the USSR must be convinced of the seriousness of purpose and the inevitability of U.S. success. This would, according to the interagency report, drive up Soviet costs to maintain an effective strategic force, develop the U.S. ability to adjust to emerging Soviet countermeasures and reactive threats, and demonstrate resolve to sustain a measured steady effort by the U.S.

The technology effort, even in its early phases, complicates and confuses Soviet plans to modernize strategic nuclear forces, the report said. "It drives them to try and develop possible countermeasures, increase emphasis on their air-breathing forces and conduct research and development on new families of weapons delivery systems. It drives the USSR away from preferred approaches of updating and proliferating existing strategic forces."



The program being recommended to the President is designed to increase the Soviets' role in cooperating with a stable strategic environment. It also is designed to "alter the Star Wars fantasy, establish the credibility and then the reality of defensive technologies."

The successful demonstration of the technology required to develop and deploy a defense system will build credibility and confidence, the report said. But the pressure to demonstrate the technology could push for rapid deployment of "marginal or brittle systems based on available technology," and this should be avoided, the report cautioned.

It proposes rapid development of technology that can deal with postulated Soviet countermeasures. This development approach also would provide a hedge against similar Soviet defensive technologies.

The interagency proposal to the President stresses that North Atlantic Treaty Organization countries and Japan should be convinced that even research and development for ballistic missile defense will enhance the potential for arms control or reductions, decrease the nuclear threat overall, increase crisis stability and improve long-term relations with the Soviet Union. "It does not alter the commitment by the U.S. to its allies' defense," the report said.

The Soviet Union has over the last decade conducted substantial research and development in this technology area, "and vigorous defensive activity is necessary to counter ballistic missile defense work by the USSR," the report added. The key to effective defense is low leakage with an indepth layered defensive system.

The boost-phase intercept is essential to the system because it destroys the missile before it can deploy multiple warheads. This minimizes the attractiveness to the Soviets of high-throw-weight missiles with large numbers of reentry vehicles.

Even a very effective boost-phase intercept capability would be augmented with post boost, midcourse and terminal interceptor defenses. "All of the concepts use some space-based assets and survivability of these is a critical issue requiring combinations of technology and tactics available or becoming available. X-ray lasers, chemical, excimer and free electron lasers, particle beams and kinetic energy hit-to-kill devices all have high potential for boost-phase intercepts," the report said.

[From Aviation Week & Space Technology, Oct. 24, 1983]

U.S. Strategic Defense Options—Study Urges Exploiting of Technologies

(By Clarence A. Robinson, Jr.)

WASHINGTON.—The Reagan Administration's Defensive Technologies Study Team has recommended a $21.1-billion development program through Fiscal 1989 to exploit emerging technologies, including an orbital array of large, new directed-energy weapons and surveillance spacecraft. The plan is aimed at providing an effective ballistic missile defense for the U.S. and its allies against Soviet nuclear weapons attacks.

While the team's report outlined a long-term technology validation approach for ballistic missile defense, it also recommended that "certain intermediate technologies can and should be demonstrated as part of the evolutionary research and development program."

The scope of the recommended ballistic missile defense program is on the same scale as the U.S. Apollo program that resulted in six lunar landings. An immediate infusion of approximately $1.4 billion in the current fiscal year is part of the team's recommendation, with about half of that amount for directed-energy weapons development and half for surveillance, acquisition and tracking technology.

The Defensive Technologies Study Team, headed by James C. Fletcher, former administrator of the National Aeronautics and Space Administration (AW&ST July 18, p. 19), concluded that a decision to proceed with the program will require development of a Saturn 5-class booster capability (about 280,000 lb. orbital payload), and the report is expected to be a factor in President Reagan's upcoming decision on development of a space station.

"A decision to proceed with ballistic missile technology development implies a decision to proceed with heavy-lift space booster development," the Fletcher study said. "We believe a space-based system may also require a continuous manned space presence. Over 100 complex and expensive satellites with missions of highest national importance can be envisioned . . . Both cost and effectiveness may justify manned systems . . . Development of a repair and refurbishment system may be the key to operational and economic viability of space-based ballistic missile defense."

The study team's report said it takes "an optimistic view of newly emerging technologies and with this viewpoint concluded that a robust, multitiered ballistic missile defense system can eventually be made to work."

The report added that the ultimate utility, effectiveness, cost, complexity and degree of technical risk in this system will depend not only on the technology, but it also will depend on reponses by the Soviet Union to the U.S. initiative, or to arms control limitations. The new technologies that make ballistic missile defense attractive, according to the Fletcher report, are:

Directed-energy weapons—Nuclear pumped X-ray laser, neutral particle beam, visible and infrared high-energy lasers.

Precision sensors—Two-dimensional optics for search and tracking, laser imaging radar, and millimeter wave radar imaging and tracking.

Electronics systems—A billion operations a second processor for optical sensors, microminiaturized electronics, and their combination with precision sensors make small hit-to-kill guided interceptors possible.

Hypervelocity gun—Based on electromagnetic railgun technology.

The study team was chartered to delve into technology that could provide a ballistic missile defense for the nation in 15-20 years, a task assigned under National Security Studies Directive 6-83. The group called on the aid of hundreds of representatives of industry and academia from June through Oct. 1. It also based its technology findings on reviews of previous strategic studies as it sought to identify all credible approaches.

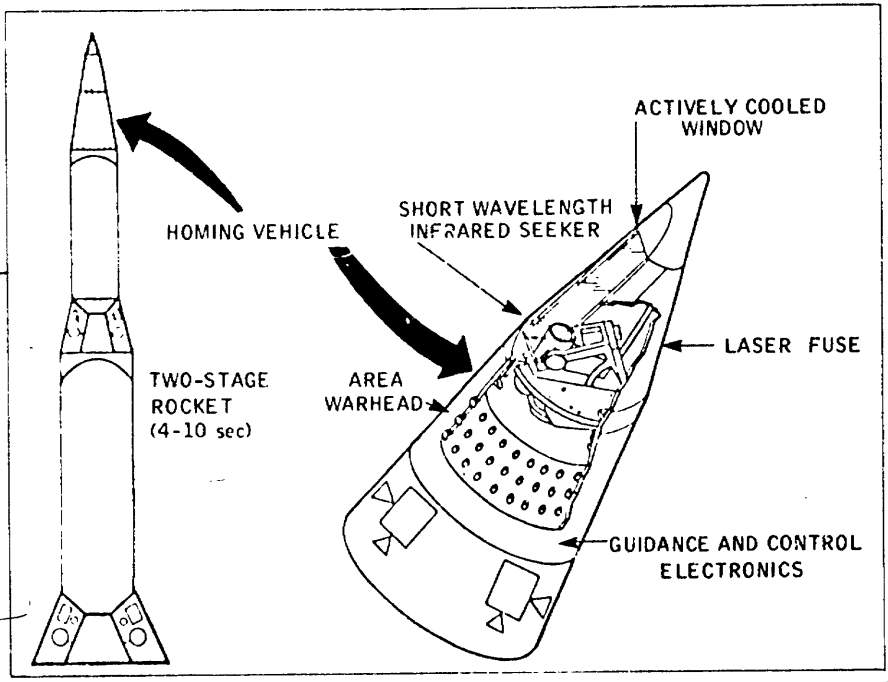
"We urge that a vigorous research and development program, broadly based but highly goal-oriented, be pursued," the report said. This program would permit informed decisions on whether to initiate, in the early 1990's an engineering validation phase leading to a deployed defensive capability after the year 2000.

"The potential exists for earlier, phased deployment against constrained [those that do not employ advanced countermeasures] threats. A detailed policy study addressing the merits of such deployment should be carried out," the report added.

The most capable ballistic missile defense systems have multiple layers. Of those layers, boost-phase intercept has the greatest leverage but also is the most difficult, the report said.

In assessing the technology becoming available for ballistic missile defense, the Fletcher study team considered a system effective enough to support a strategic ini-

tiative of forcing the U.S. and the Soviet Union to begin to rely on defense, not offense, as a basis for national strategic policy.



Chief among near-term ballistic missile defense advanced technologies for terminal and midcourse phases of a layered defensive system are kinetic energy kill weapons. One of the more mature is a hypersonic interceptor, a 5,000-7,000-kg. (11,000-15,400-lb.) launch weight weapon armed with a pellet area warhead, depicted in an artist's concept. The weapon is maneuvered by rocket propulsion and terminally guided to the target. It travels at 5-6 km./sec. (3.1-3.7 mi./sec.) and has a 200-km. (124-mi.) terminal intercept range, and a 15-50-km. (9.3-31-mi.) altitude capability. Note the laser fuse and short wavelength infrared seeker.

A more specific study mission of stopping 99.9% of the attacking ballistic missile force was considered, as were unrestrained countermeasures by the USSR as a response. Prior Defense Dept. studies have shown that the level of hardness that could be achieved by the Soviet Union with ballistic missile boosters is approximately 20 kilojoules/cm.^{2}. Present booster hardness levels are 0.4 to 2 kilojoules/cm.^{2}.

While it is not technically credible to provide a ballistic missile defense that is 99.9% leak proof, the report said, ballistic missile defense does not have to be perfect to be worth its cost. "Rather, defense can meet the President's objectives by providing an incentive for the Soviet Union to reduce reliance on ballistic missiles and agree to arms control limitations on their numbers and capabilities."

Recent advances in technology justify another evaluation of ballistic missiles defense as a major change in strategy, according to the team's study report. "In the 1960s, there were no credible concepts for boost-phase intercept. Today, there are multiple approaches based on directed-energy concepts and kinetic energy kill mechanisms," the report said.

In the past, midcourse intercepts were hampered by lack of credible decoy discrimination, the cost per intercept and undesirable collateral nuclear weapons effects from interceptor warheads.

Inexpensive interceptors

Multispectral sensing for discrimination, launch-to-destruction tracking in midcourse, and small hit-to-kill vehicles promise inexpensive interceptors capable of overcoming midcourse limitations.

Technology available today provides the potential to discriminate between penetration aids and decoys at high altitudes. Improved interceptor technology can be coupled for boost-phase and midcourse intercepts to disrupt pattern attacks.

Robust terminal defense seems attainable, the report said, adding that computer hardware and software and signal processing capable of supporting a multilayered defense is believed to permit realization of the complex command and control systems required.

"The Soviets are believed to have a capability to widely deploy a ballistic missile defense system in a relatively short time," the report explained. "With appropriate modifications, such deployment could provide the basis for a major capability for direct ascent antisatellite operations. The Soviet Union can be expected to boost single-launch payloads of 150,000-250,000 kg. (330,693-551,155 lb.) by the end of the decade. One strategy might be to include in those launches a directed-energy weapon prototype demonstration of their technical prowess, as part of an arms control negotiating posture, or simply as a consequence of their emphasis on early operational experience and evolutionary development."

Viable option

To make a multitiered ballistic missile defense system for the U.S. a viable option, the report said that the space transportation system must be expanded to provide the capability to launch about 100 tons to medium orbits tens of times a year.

Space logistical support will require heavy-lift launch vehicles for large U.S. systems, resupply and servicing of space assets, a source of materials for shielding, and orbital transfer vehicles.

The plan mapped out by the Fletcher panel concentrates on critical technologies that "are the long poles in the tent. These include boost-phase intercept of ballistic missiles, especially those hardened against laser radiation, post-boost intercept, and handling of large threat clouds, including reentry vehicles, decoys and other material, during midcourse and high reentry altitudes."

Other technological requirements include survivability of space-based assets for defense when threatened with nuclear weapons, or counterparts to U.S. directed-energy weapons. Inexpensive interceptors for nonnuclear midcourse and early reentry kills are necessary, along with tools for developing battle management software.

The technology limited plan proposed by the team would concentrate between now and 1986 on establishing technology needed to scale selected beam generators to the performance levels required for ballistic missile defense. This schedule will require a significant and immediate acceleration of the current neutral particle beam, excimer, free electron and nuclear-pumped X-ray laser while continuing the current infrared chemical laser program.

The plan also includes:

Expanding optical beam director programs to insure that technical feasibility and scalability of beam control system, optics, phased arrays and optical structures are demonstrated. Near-term emphasis is on resolving issues that are generic to all laser concepts as well as demonstrating technical feasibility.

Exploitation of acquisition, tracking, imaging and designation for surveillance, discrimination and midcourse interceptor technology. Existing programs would be expanded to include hybrid ground/space laser and particle-beam concepts. A separate program would be initiated to develop advanced tracking and pointing technology for the Lawrence Livermore Laboratory Excalibur bomb-pumped X-ray laser to provide feasibility and scaling demonstrations.

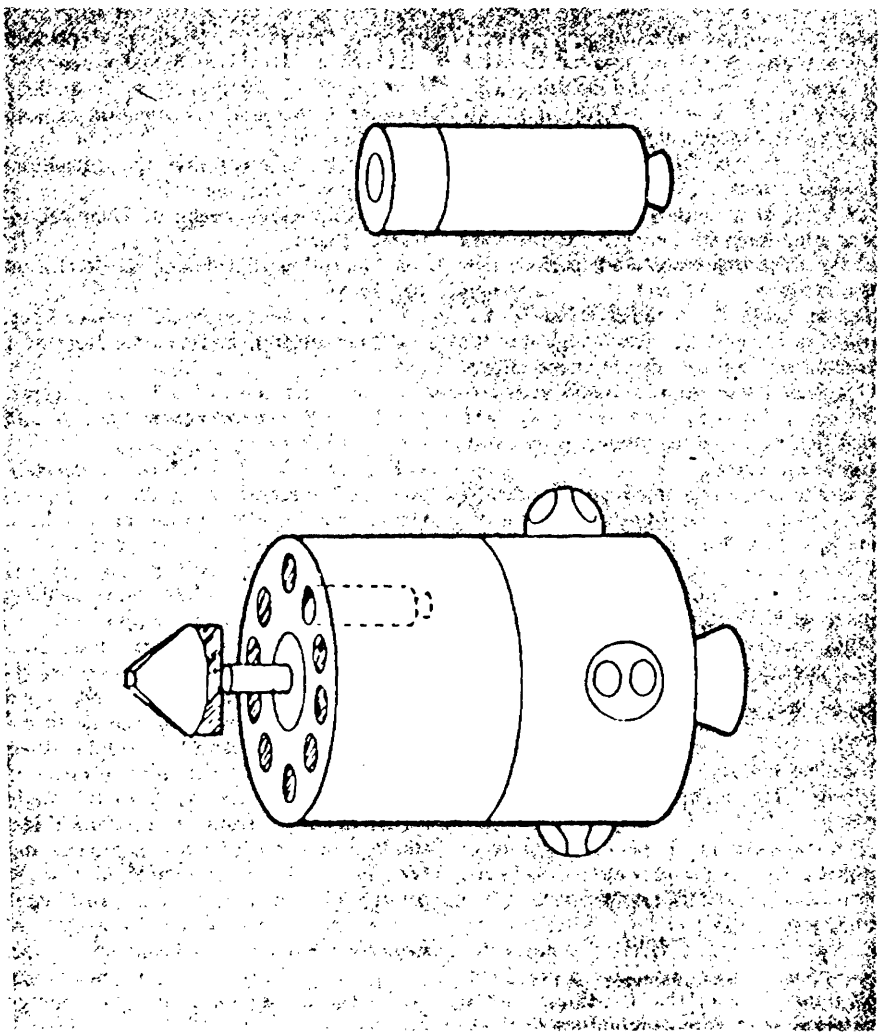
Increasing funding support to pursue promising innovative concepts to the point where their relevance and performance can credibly be estimated and decisions can be made to establish separate programs or integrate the technology into the mainstream concept development efforts. This would call upon a broad sector of university, industrial and laboratory communities to avoid overlooking the most useful approach.

The program schedule recommended by the Fletcher group brings all candidate concepts to at least the level of feasibility demonstrations in 1986-1987. At this point, the feasibility outcomes are combined with the assessment of achievable target hardening to select the most promising concepts for scaling demonstrations.

Three priority areas

The study team's report establishes three technology development areas by priority. The highest of these priorities includes lethality.

"An assessment of the vulnerability of responsively hardened targets to lasers, particle-beam and X-ray weapons is the single most important issue in determining whether there is a feasible concept for development and ultimate deployment. We must postulate that the threat will be hardened to the maximum practical extent."



Porcupine satellite defense system proposed by the Defensive Technologies Study Team depicted in drawing above is a self-contained, 20,000-kg. (44,100-lb.) system armed with 50 kill vehicles. The kill vehicle is a 150-kg. (330-lb.) mass vehicle to deliver 6 km./sec. (3.7 mi./sec.) velocity with a 5-kg. (11-lb.) terminal stage. Note the laser radar sensor and the passive surveillance system. The team's report said that conventional technology as well as directed-energy weapons are required for defense of space platforms with firing rates of 0.1-1./sec., and from 50-500 engagements per platform.

The technology in the first priority is that with elements that have broad application, high leverage on research and development costs, and are vital to defining early program scope and direciton. These are:

Nuclear-driven X-ray lasers.

Large, deployable space optics.

Acquisition, pointing and tracking.

Atmospheric compensation for ground-based short wavelength lasers.

The second priority in technology development proposed by the study team includes major elements that are more specific to a limited aspect of directed-energy weapons that are necessary for fundamental feasibility. There are:

Neutral particle-beam weapons technology.

Excimer and free electron lasers.

Chemical infrared laser technology.

New and innovative concepts.

This second priority category is concerned with demonstrating the feasibility of generating the required high-brightness beams with appropriate efficiencies to insure the optional approaches are well characterized. It also includes nuclear-driven particle and microwave beam technology. The third technological priority proposed by the report includes major efforts involving integration of technology building blocks and investigation of scaling. These are:

Space demonstration to acquisition, pointing and tracking.

Cylindrical 2-megawatt chemical infrared laser.

Neutral particle-beam accelerator at 100 MeV.

Single-pulse megajoule excimer laser.

Free electron and excimer laser at 1 megawatt.

New nuclear weapon/beam concepts.

Nuclear reactor power systems and power conditioning technology.

The technologies proposed for development by the report are predicated on providing the capability to defend the U.S. effectively against a near simultaneous launch of 1,000 ballistic missiles by the USSR, armed with 10,000 reentry vehicles each carrying a nuclear weapon.

The nuclear-pumped X-ray laser is a high-interest technology as a potential capability for handling a massive salvo launch threat. It also is of interest to determine against U.S. defensive systems.

A major goal, according to the study report, is early resolution of technical feasibility issues in defining laser physics and verifying performance scaling in a series of underground tests. Critical X-ray laser device issues include demonstration of high efficiency and low beam divergence.

"Decisions on the value of this concept are based on demonstration of energy scaling, the fabrication of laser rod bundles, and pointing of multiple rods at multiple targets with accuracy consistent with beam-divergence," the report said.

New technologies and concepts emerging from the defensive technologies study include:

Surveillance, acquisition and tracking—A 60-GHz. geostationary imaging radar, laser imaging radar, long-wavelength infrared passive search system and airborne optical system.

Kinetic interceptors—Exoatmospheric nonnuclear kill, high endoatmospheric nonnuclear kill and hypervelocity guns.

Space asset survivability.

The airborne optical system is considered one of the highest priorities, especially for application on both theater and intercontinental ballistic missile defense. The long-endurance aerial platform carrying acquisition, discrimination, tracking and fire control equipment would cover a defense radius of 750 km. (466 mi.). It would carry aloft long wavelength infrared sensors and laser ranging equipment to provide detection at a range of 1,600 km. (994 mi.). As an important adjunct to a midcourse or terminal layer of the defense, the airborne system would observe interaction with the atmosphere for discrimination.

Field of view

The 60-GHz. geostationary imaging radar would operate in space at a 40,000-km. (24,840-mi.) altitude. The number of elements in the radar would be 2.3×10^7, and the antenna diameter would be 115 meters. The field of view would be 6 deg. $\times$ 12 deg., with a target area coverage of 4,000 $\times$ 8,000 km. (2,484 $\times$ 4,968 mi.).

Another surveillance technology included in the study is the midcourse surveillance discrimination and tracking system, a multisensor platform operating at a

10,000-km. (6,210-mi.) altitude. The system would operate with 25 spacecraft each with a range of 17,000 km. (10,557 mi.), and a self-defense capability. The sensor would operate with long wavelength infrared passive optics with a 4-meter (13.1-ft.) diameter, a field of view of 4 deg. × 4 deg., and a resolution of 100 meters × 100 meters (328 × 328 ft.).

Included on the sensor platform would be an optical inverse synthetic aperture imager with a power of 100 kw., an optics diameter of 4 meters, the capability of one target image-sec. and a 20-cm. (7.88-in.) resolution.

In the layered defense concept, early options emerged in the report. These include defense against tactical nuclear ballistic missiles, especially for application against Soviet missiles deployed against North Atlantic Treaty Organization nations. Required technologies for this application include the airborne optical system and endoatmospheric and exoatmospheric nonnuclear kill interceptors. This system would provide the capability for midcourse intercepts of ballistic missiles at up to 1,000 km. (621 mi), and high endoatmospheric intercepts at 45 km. (27.9 mi.) and again at 15 km. (9.3 mi.).

System demonstration is feasible by 1990, with added funding of $500-600 million needed in 1985-1990 for the concept.

Another concept in the study is a two-phase system for low-leakage defense of U.S. high-value targets. It also includes the airborne optical system, inexpensive nonnuclear endoatmospheric and exoatmospheric interceptors, and midcourse satellite sensors, and it relies on a geostationary boost-phase detection system.

This is part of a later three-phase defensive system and includes an enhanced early warning spacecraft improved for resolution and survivability.

Other aspects of the layered defensive system include:

Midcourse sensor constellation—100 satellites with each weighing 20,000 kg. (49,000 lb.) for discrimination, precision tracking and designation.

Midcourse interceptor—approximately 10,000 infrared homing hit-to-kill interceptors, each weighing 5 kg. (11 lb.), and a 200-500-kg. (490-1,100-lb.) booster for the interceptor.

Airborne optical system—approximately 20 platforms, either remotely piloted or manned with long wavelength infrared and laser sensors.

Terminal interceptor available by 1990, a 6,000-kg. (13,200 lb.) missile armed with infrared homing nonnuclear kill devices. This interceptor would have a velocity of 6 km./sec. (3.7 mi./sec.) and a coverage radius of 100 km. (62.1 mi.).

A midcourse long wavelength infrared and ultraviolet sensor spacecraft would be used for post-boost tracking. The two-phase defense system could be demonstrated with increased funding by the early 1990s, and provide a 1-2% leakage capability against 5,000 to 10,000 reentry vehicles, the report stated.

The Fletcher panel report concluded that current technology alone will not provide solutions to unconstrained long-term Soviet threats. But the report added that there are significant milestones and demonstrations that can be performed in the next 10 years. Other conclusions include:

Ballistic missile defense will demand strong central management, dedication and perseverance.

Capable systems have multiple layers, with boost phase intercept providing the greatest leverage.

Interactions between offensive and defensive forces are vital to maintaining system effectiveness against responsive threats, which require continuing intelligence, analyses of countermeasures and counter-countermeasures. Current data bases are inadequate.

Survivability, especially of space-based assets, is a serious problem requiring combinations of armoring, deception, mobility, active defense, radiation hardening, and tactics coupled to necessary policy. Kinetic energy weapons for terminal defense of space assets are technically feasible but require engineering advances.

Boost-phase intercepts have the potential to drive the USSR away from large, highly fractionated multiple reentry vehicles.

Hardness of current Soviet boosters is such that many projected laser weapons could destroy them. However, straightforward modifications can improve hardening dramatically. Redesigned boosters with higher velocities, spinning and ablative materials would require U.S. lasers with high brightness of approximately 10^{22} w./steerradian, and less than 0.1 sec. retargeting.

Feasibility of the X-ray laser demonstrated in two tests required validation at moderate brightness—10^{19} joules/steerradian, plus upgrading to three orders of magnitude.

Neutral particle-beam accelerators and power supplies could be effective against current threats, but for responsive threats advances are necessary to 200 MeV., with power supplies of 100 megawatts for up to 600 sec.

[From Aviation Week & Space Technology, Oct. 24, 1983]

Defensive Technologies Study Sets Funding Profile Options

WASHINGTON.—A long-term ballistic missile development plan proposed by the Defensive Technologies Study Team following a four-month study earmarks $6.2 billion for directed-energy weapons and $5.2 billion for conventional interceptor work over the next five fiscal years.

The development plan laid out by the study group is pointed toward resolving technical issues through development and demonstrations contributing to total systems effectiveness rather than an early deployment capability.

"Our goal was to provide the basis for selecting the technology paths to follow when a specific defensive strategy is chosen for implementation," the team's report said.

The study team developed two approaches to funding ballistic missile defense technology. One is technology limited, a program that proceeds as fast as the technology can reasonably allow without excessive duplication. It assumes that additional funding can be made available that is consistent with the priority of this program.

The other funding approach is a fiscally constrained program. In this approach, the study team used the same funding level for development in Fiscal 1984 as the technology limited program. But in Fiscal 1985 through Fiscal 1989, funding was based on the program objective memorandum totals submitted in May by the Defense Dept., the services and other agencies.

The recommended development plan by the team includes $1.3 billion in Fiscal 1984, $2.3 billion in fiscal 1985, $3.4 billion in Fiscal 1986, $4.3 billion in Fiscal 1987, $4.6 billion in fiscal 1988 and $4.9 billion in Fiscal 1989.

The fiscally constrained plan provides $1.3 billion, $1.9 billion, $2.5 billion, $3.1 billion, $3.7 billion and $4.3 billion in Fiscal 1984 through Fiscal 1989, respectively.

The team's recommended limited plan for development of a ballistic missile defense to provide decision milestones includes:

Surveillance, acquisition and tracking—$7.7 billion through Fiscal 1989. This includes $486 million, $793 million, $1.1 billion, $1.5 billion, $1.8 billion and $2.1 billion in Fiscal 1984 through Fiscal 1989, respectively.

Directed-energy weapons—High-energy lasers and particle beam—$6.2 billion through Fiscal 1989. This includes $530 million, $750 million, $1 billion. $1.2 billion, $1.3 billion and $1.3 billion in Fiscal 1984 through 1989, respectively.

Conventional ballistic missile weapons—$5.2 billion through Fiscal 1989. This includes $258 million, $562 million, $903 million, $1.2 billion, $1.2 billion and $1.1 billion in Fiscal 1984 through Fiscal 1989, respectively.

Battle management, command, control and communications—$366 million through Fiscal 1989. This includes the use of existing funding in Fiscal 1984, and $34 million, and $51 million, $68 million, $91 million and $122 million in Fiscal 1985 through 1989, respectively.

Survivability and target hardness—$775 million through Fiscal 1989. This includes $125 million, $75 million, $125 million in Fiscal 1984 through 1986, respectively, and $150 million a year in Fiscal 1987 through 1989.

Lethality—$400 million through Fiscal 1989. This includes $59 million, $88 million, $91 million, $92 million, $50 million and $20 million in Fiscal 1984 through 1989, respectively.

Selected support systems—$221 million through Fiscal 1989 for power supply development. This includes $4 million, $11 million, $22 million, $41 million, $41 million and $102 million in Fiscal 1984 through 1989, respectively.

Systems concepts—$456 million through Fiscal 1989. This includes $36 million, $50 million, $70 million from Fiscal 1984 through 1986, respectively, and $100 million a year from Fiscal year 1987 through 1989.

One of the key areas of emphasis in the recommended development plan by the study team is new, innovative technology and concepts. Funding in this area includes $20 million, $45 million, $90 million, $100 million, $100 million and $100 million in Fiscal 1984 through 1989, respectively.

Funding in the area of directed-energy weapons includes:

Chemical infrared high-energy lasers--$55 million, $65 million, $90 million, $90 million, $90 million and $90 million in Fiscal 1984 through 1989 respectively.

Excimer short wavelength lasers—$35 million in Fiscal 1984, $55 million in Fiscal 1985 and $90 million a year from Fiscal 1986 through 1989.

Free electron lasers—$25 million, $45 million, $75 million, $80 million, $90 million and $90 million in Fiscal 1984 through 1989, respectively.

Neutral particle beam—$10 million, $35 million, $50 million, $90 million, $100 million and $100 million in Fiscal 1984 through 1989, respectively.

Nuclear pumped X-ray laser—$100 million in Fiscal 1984, $120 in Fiscal 1985, $150 million in Fiscal 1986, and $175 million a year in 1987 through 1989.

Other directed-energy weapons related to nuclear devices—$150 million in Fiscal 1984, $65 million in Fiscal 1985, $100 million in Fiscal 1986 and $125 million a year in Fiscal 1987 through 1989.

Funding recommended for related directed-energy technology includes:

Large optics—$25 million and $40 million in Fiscal 1984 and 1985, respectively and $50 million a year in Fiscal 1986 through 1989.

Acquisition, tracking and pointing—$205 million, $250 million, $310 million, $320 million, $350 million and $350 million in Fiscal 1984 through 1989, respectively.

Space-based power—$5 million, $30 million, $65 million, $65 milllion, $80 million and $80 million in Fiscal 1984 through 1989, respectively.

The study group's investment strategy is based on two premises: first, that the most badly needed technology is usually the least mature, and second, that there are minor technical uncertainties associated with it.

The recomendations also includes investment in parallel technology paths to resolve issues that have maximum impact on selecting the program's future direction and pace.

It provides for continued investment of approximately 5% of available resources in high-risk, innovative areas that offer high payoffs. The funding approach also applies limited resources to system-level engineering until a second major decision point is reached.

In the technology limited funding approach, the team assumes that $100 million would be reprogramed in Fiscal 1984 above the budget requests.

[From Aviation Week & Space Technology, Oct. 31, 1983]

U.S. Strategic Defense Options—Shuttle May Aid in Space Weapons Test

(By Clarence A. Robinson, Jr.)

Washington.—Defense Dept. and the Air Force are considering an indusry proposal to use the space shuttle and begin within two years technology demonstrations in orbit for space-based weaponry to defend U.S. staellites. The technology later could be applied to ballistic missile boost-phase intercepts using directed-energy weapons for defense.

Teledyne Brown Engineering's proposal, known as Validator, could result in the final phase of flight test in space of a demonstration of a high-energy laser of kinetic energy hit-to-kill weapon against spacecraft targets.

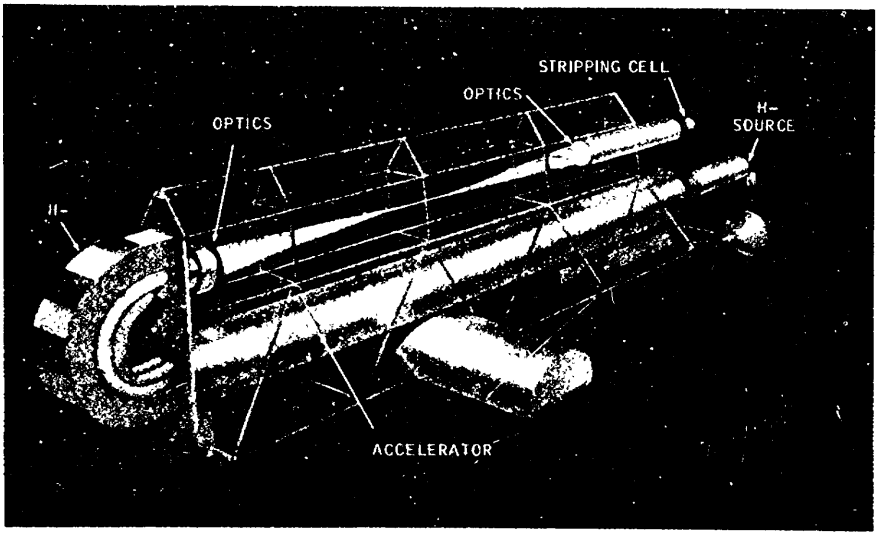
A three-phased demonstration program, the Validator concept is based on utilizing existing technologies and off-the-shelf hardware, some of which has already been flight tested on boosters in the Army's ballistic missile defense program.

The Teledyne Brown proposal generally follows recommendations made to the President by a Senior Interagency Group (AW&ST Oct. 17, p. 16), and Defensive Technologies Study Team (AW&ST Oct. 24, p. 50) in reports on an advanced ballistic missile defensive system for the U.S. Both groups called for early feasibility demonstrations of the technologies involved.

Defense Secretary Caspar W. Weinberger also recommended to Reagan a $26-billion program for defensive technology development from Fiscal 1985 through Fiscal 1989. It includes options for early demonstrations.

Close friends and advisers of the President have stressed to Reagan the importance of early technology demonstrations to establish the credibility of U.S. technological prowess for an advanced ballistic missile defense capability. This would dispel the aura of Star Wars associated with the President's plan to move the nation away from the offense-dominated mutual assured destruction strategy of the superpowers to an assured survival defensive capability for the nation.

Briefings of the Validator concept were presented to the Defensive Technologies Study Team, the Defense Dept.'s Advanced Research Projects Agency and to USAF's Space Div.



Neutral particle beam weapon for boost-phase intercept of nuclear-armed ballistic missiles is depicted in an artist's concept. The design would provide a 200 MeV hydrogen beam with low divergence relatively insensitive to hardening countermeasures by the USSR. Los Alamos Scientific Laboratory is involved in developing this technology in a program called White Horse. From 10 to 40 particle beam battle stations, each weighing approximately 60,000 kg (61,728 lb), would be based in low Earth orbit. The weapons would have a residual capability to destroy in midcourse trajectory reentry vehicles that escape destruction on the booster shortly after launch.

In the initial phase of Validator, a long wavelength infrared sensor would be tested along with a low-light-level electro-optical sensor in a package on the shuttle oribter. The technology also applies to USAF's space-based surveillance system, a separate new program, and to acquisition, pointing and tracking systems generally. The first phase of the Validator program would cost approximately $50 million. The estimated cost through all three proposed phases would be $500 million.

The first phase experiments could be accommodated in scheduled shuttle missions, Pentagon officials said, using the multipurpose experiment support structure already tested in orbit on Mission 7 of the shuttle.

"The Validator test equipment mounted on the multipurpose support structure would take only about 3 ft. in the shuttle cargo bay and the support structure is already on the shuttle's manifest for experiments," one Pentagon official said. "The NASA support structure would be adapted to a small military payload.

The demonstration would provide badly needed data for a space surveillance system and for acquisition, printing and tracking required for space-based laser weapons. The initial equipment demonstrated would take advantage of existing long wavelength infrared sensors using a sensor in the class of the Hughes Aircraft/ Army designating optical tracker. The sensor was flight tested five times on boosters fired into space in a program with Boeing as the prime contractor.

Other long wavelength infrared sensors are under consideration for the Validator flight. A long wavelength sensor by Vought Corp., built for the Defense Advanced Research Projects Agency Scoop program, is one. It was flight tested from White Sands Missile Range, N.M., for satellite tracking tests. An Air Force SIRE (space infrared experiment) infrared sensor also could be available for the test.

The first phase could include up to three missions in the shuttle using the infrared sensor coupled to a television camera with a 25-centimeter aperture. "The concept is to use the infrared sensor to acquire the target and hand it over to the electro-optical sensor with its higher resolution and imaging capability for precision tracking," a Defense Dept. official explained. "We could use this approach to speed

up and obtain critical data that apply to space-based sensor across the board for application to any type of orbiting defensive weapon system. The technology also would apply directly to antisatellite or defensive satellite systems."

In the second phase of the proposed program, similar experiments would be conducted with a larger 1-meter-dia. aperture on the low-light-level TV sensor for increased resolution. A low-power laser for target illumination might be added to the shuttle package. The laser would be a frequency doubled neodymium YAG off-the-shelf device. Average power is only a few watts, with peak power to 60 megawatts.

This experiment with the long wavelength infrared sensor, low-light-level television and illuminating laser would be to demonstrate active target tracking, and semi-active homing, if a laser-guided missile were used for target intercept. The company has proposed in the final phase the use of an existing hydrogen or deuterium fluoride laser operating at 2 megawatts as a logical progression for test against a target vehicle. This phase also could include a terminal homing hit-to-kill kinetic energy weapon.

Some Defensive Technologies Study Team members wanted the demonstration to be based in the third phase on target intercepts using a hit-to-kill device fired from the shuttle at a target.

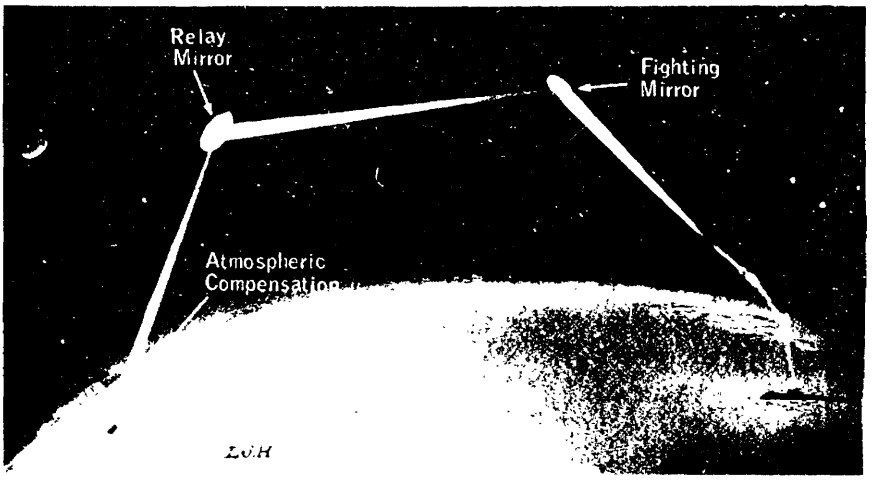
"This is a competing idea for the final test if the program is approved, but this test and the use of a high-energy laser are not exclusive," a White House official

confirmed. "Until recently there hasn't been much support for using a laser in the Validator concept, but that may all change. There is pressure for the President to establish the credibility of the technology, and this could mean coupling a laser weapon in space with a target."

A number of feasibility demonstrations are being proposed to the Defense Advanced Research Projects Agency (DARPA) that could accelerate the technology for an advanced ballistic missile defense system. Other technology already in development in parallel service or laboratory programs could be applied to early feasibility demonstrations.

A recent DARPA concept is known as Skylight. It would take advantage of the Hughes Aircraft beam director in the canceled Navy Sea Lite laser program, and integrate the optical system with a 3.8-micron, 2-megawatt deuterium fluoride laser device to conduct ground-based tests with a pointing precision of under 100 nanoradians root mean square.

"It could be used in tests against targets for a gee whiz experiment, but it would not provide a basic military capability," an Administration official said. It has the potential to provide lethality demonstrations against spacecraft targets. "Another idea is predicated on a ground-based, medium-range applied technology approach using the small 500-kw. TRW 3.8-micron deuterium fluoride chemical laser mated with a 1-meter-dia. telescope from the Fire Pond program," he said.



Visible wavelength electric laser is depicted in an artist's concept as a 10-megawatt device taking advantage of adaptive optics to overcome atmospheric turbulence to propagate a beam to orbiting relay mirrors. The beam is relayed in turn to orbiting fighting mirrors to engage ballistic missiles shortly after launch in the boost phase. This concept is designed to provide a high efficiency laser device with pointing and tracking to 20 nanoradians. The device can provide sequential thermal kills and impulse kills of targets. The orbiting mirrors would include 10-40 platforms at an altitude of 1,000 km. (621 mi.).

Fire Pond is another laser development effort by Massachusetts Institute of Technology and Lincoln Laboratory. "This would provide a precision pointing and tracking demonstration against targets in orbit."

One of the technology-development programs strongly recommended to the President in studies of U.S. ballistic missile defensive technology is the use of small, inexpensive rare gas halide excimer lasers with a ground-based beam director to propagate the laser beam through the atmosphere to an orbiting relay mirror for ballistic missile defense boost-phase engagements.

The same technology could be used for antisatellite missions, with feasibility experiments within five years, Defense Dept. experts said. Several approaches are being studied for the optics requirement, which is likely to be a 10-meter-dia. mirror.

A high-quality laser beam would be extracted from low-cost laser devices using a hydrogen Raman cell (AW&ST July 18, p. 18). The technology is considered a major breakthrough to enhance laser performance including scaling to higher power devices with defraction-limited capability. Adaptive optics would be used to compensate for atmospheric turbulence.

One optical system concept for the ground-based excimer laser with its short visible wavelength benefits is based on phased-array type technology with a segmented mirror functioning along the lines of an electrically steered radar beam. Several small excimer laser devices could be used to illuminate segments. The beams would be combined and remain in phase for propagation to a target in space.

The excimer laser device that would be used in that concept is expected to come from DARPA's EMRLD (excimer repetitively pulsed laser device) program, a competitive effort involving industry. Avco and Rocketdyne are teamed, and are competing against TRW, Northrop and Maxwell Laboratory. The companies are exploring scaling to higher powers with a xenon fluoride laser. Competition is expected to continue into 1984.

"In the past few months, we have had a major breakthrough with excimer lasers, methods that allow an extension of performance in several different directions," a Defense official confirmed. "This same technology is being used to scale to very high average power. It implies lower cost and defraction-limited beam quality. We plan to conduct field tests through 1985 to demonstrate the feasibility."

Yet another related program managed by USAF's Space Div. is the strategic laser technology program. It evaluates the viability of space-based lasers, including the

capability of a 10-megawatt/10-meter dia. device, costs, spacecraft vulnerability, target vulnerability and hardening, and beam control. Each of four industry teams taking part in the program are funded at approximately $2 million a year. The contractors include Boeing-Hughes Aircraft, Martin Marietta/United Technologies, Rockwell International and Lockheed/TRW-Eastman Kodak.

In the past year or so, according to National Security Council officials, funding has caused the Defense Dept. to cut back on some of the major facets of DARPA's Triad chemical laser program. Both the Talon Gold and LODE (large optics demonstration experiment) programs have been reduced in scope.

The technology involved applies not only to space-based chemical mid-infrared wavelength lasers but to surveillance, acquisition, pointing and tracking systems that would be utilized by short wave-length excimer, free electron or nuclear pumped X-ray lasers.

"The NSC, Office of Science and Technology Policy and DARPA are all agreed that the technologies in Talon Gold and LODE are absolutely vital to the new ballistic missile defense effort, and that funding may be increased to accelerate development," a White House official said. Lockheed, prime contractor for LODE, was earlier ordered by DARPA to cut back on the scope of the program to meet a $40-million allocation in the budget for the program, he said. During the preliminary design review of the program, which will continue through December, the contractor determined that it will cost approximately $80 million for fabrication and testing of the 4-meter-dia. system through Fiscal 1988.

USAF is obtaining the active mirror for LODE from Itek at a cost of about $25 million to provide it to Lockheed as government-furnished equipment. Under the possibility of a restructured program, the White House official said, Lockheed might only perform generic or basic wavefront control experiments with the segmented adaptive optics. "This approach would eliminate wavefront sensing, structural dynamics and control interaction—all the experiments that we need for a number of applications," an official said. Other approaches are being considered to resolve the funding problem that includes wavefront sensing.

Talon Gold pointing and tracking experiments were reduced two years ago to remain within funding profiles. Lockheed has a $40-million contract for shuttle integation of the device. In restructuring the program, DARPA removed the infrared acquisition and tracking capability, leaving only the visible pointing experiment. It uses a frequency-doubled neodymium YAG laser at 1.06 microns with a detector for a closed-loop experiment.

The TRW Alpha hydrogen fluoride 2-megwatt cylindrical laser, the third element in the Triad program, has passed the critical design review development phase and is being fabricated. The basic device, Defense Dept. officials said, can readily be scaled to a 25-megawatt laser by increasing the flow and lengthening the cavity.

The $170-million Alpha program is slated to lead to testing with the laser at TRW's Capistrano, Calif., facility in 1987. "Essentially, the recommendation of the Fletcher panel places chemical lasers in idle while accelerating shorter wavelength devices. This is the most mature technology base the nation has, and it should be kept going on a technology-limited basis," the official continued.

He added that there appears to be a consensus that the key to effective defense in the boost phase is shorter wavelength lasers or particle-beam weapons. "But you don't jump off the cliff until you've tested the parachute, and that means continuing with mid-infrared chemical and shorter wavelength lasers," he said.

The Air Force has awarded contracts to TRW and Rocketdyne to develop a 1.3-micron oxygen iodine shorter wavelength chemical laser. It could be used for any number of applications, including spacebased tests as part of an antisatellite capability, the official said.

The Defensive Technologies Study Team's report said that the next major step in infrared chemical laser development—a 2-megawatt experiment—should be carried out.

"Although the infrared chemical laser is perceived by some to have limited capabilities against responsive threats, use of large, phased-array optics may allow this concept to compete very favorably. Therefore, the panel recommends this program be continued in concert with other concept screening activities. We have concluded that establishing the feasibility and scalability of this technology and its associated large optics to 10^{22} joules/steerradian class systems, while pursuing in parallel the short/-wavelength, free electron laser and excimer technologies, represents a balanced program," the report by the Fletcher panel said.

The panel said that even with one of the most mature technologies—mid-infrared chemical lasers—"there are six to eight orders of magnitude difference between required and demonstrated performance. To understand what this difference means,

one can note that the chemical laser program is structured to achieve five orders of magnitude increases in brightness in the decade between 1978 and 1988."

The panel assessment of the current status of directed energy weapons technology includes:

Chemical lasers at 1.3- and 2.7-micron wavelengths to address scaling of the subsystems to performance required for antisatellite, antiair and limited ballistic missile defense as a multimission space based system.

Shorter wavelength lasers in ultraviolet and visible spectra currently in technical feasibility/design verification stages. Major emphasis is on excimer and free electron devices. An integrated demonstration of a ground-based laser antisatellite system using an excimer laser is being considered and would provide groundwork for the laser relay concept in device scaling, atmospheric compensation and ground segment beam control.

Neutral particle-beam efforts focused on demonstrating component feasibility on a laboratory scale. The challenge is to provide sufficiently low beam divergence at high current and high energy (of the order of 0.25 to 1 amp. and several hundred MeV. for structural kill). This would provide brightness levels of 10^{20} to 10^{21} joules/steerradian, to demonstrate techniques for beam sensing and pointing, and to reduce accelerator size.

Nuclear-driven X-ray lasers technology based on two partially successful underground tests. A series of underground tests are required to demonstrate laser physics and scaling potential to a brightness of 10^{22} joules/steerradian. Acquisition and tracking targets and pointing multiple beams to requisite precision of 10 microradians are required.

"Neutral particle-beams require demonstration of the basic elements of high brightness sources, the first stages of acceleration and beam direction sensing before scale-up to high energy is warranted," the Fletcher report said.

In addition, new techniques for electron stripping with minimal divergence growth would greatly enhance neutral particle-beam capability, the report continued.

"Infrared chemical lasers are approaching proof of scalability," the report added. "The critical issues are to show near diffraction-limited beam quality with a cylindrical cavity configuration and higher mass efficiency.

Excimer laser technology needs to demonstrate that power levels can be scaled to the multimegawatt power required. "Short wavelength free electron lasers must be demonstrated with good beam quality at high power and high efficiency—20-30%," the report continued.

The program recommended by the Defensive Technologies Study Team would bring all the candidate concepts to at least the level of feasibility demonstration in 1986-87. At this point, feasibility outcomes would be combined with the results of achievable target hardening to select the most promising concepts for scaling demonstrations.

This would lead to pursuing multiple concepts throughout the scaling phase with high confidence in starting full-scale validation prototypes in early 1990s.

The top priority is to establish credible estimates of the vulnerability of ballistic missile boosters, post-boost vehicles, reentry vehicles and penetration aids, according to the panel's report. "Such efforts must focus on maximum practical hardening to resist the various forms of directed energy beams." A 1986 milestone has been established for this.

Prior to 1986, the major concentration will be on establishing scaling technology for selected beam generators to performance levels required for ballistic missile defense. This will require a significant and immediate acceleration of neutral particle beam, excimer, free electron, and X-ray laser programs while continuing the current chemical laser program.

Thermal kill hydrogen fluoride lasers that operate at 2.7 microns at a demonstrated capability of 10^{15} w./steerradian need to be increased to 10^{20} to 2×10^{22} w./steerradian. This is required to counter anticipated hardening by the Soviets.

Performance of other directed-energy weapons from demonstrated levels to meet responsive threats include:

Pulsed lasers—From 10^{3} to 10^{4} joules/pulse demonstrated to 10^{21} to 10^{22} joules/steerradian, 10^{7} joules/pulse.

Neutral particle beam—From 10^{18} joules/steerradian in a 1-km. long accelerator to 50 mega-amperes, 400 MeV. 1 rad. in a space compatible design.

Hit-to-kill kinetic energy rockets—From 15 kg. at a cost of $6 million each with a circular error probability (CEP) of 1-2 meters to 1-2 kg. at a cost of $200,000 each with a 50-CM. CEP.

Electromagnetic railguns—From a velocity of 8 km./sec., 1-shot/hr. to 20 km./sec. with 1-3 shots/sec. with a 10^5 g tolerant sensor. The present sensor is 2×2^4 g tolerant.

[From Aviation Week & Space Technology, Jan. 23, 1984]

U.S. Realigns Program on Ballistic Missile Defense

(By Clarence A. Robinson, Jr.)

WASHINGTON.—The Defense Dept. is realigning U.S. ballistic missile defense research and development programs into strategic defense initiatives, adding approximately $13 billion in new funding through Fiscal 1989 and bringing the total effort to approximately $25 billion in the new five-year defense plan.

In the proposed realignment, 25 ballistic missile defense program elements will be consolidated into five large programs. Funding will be rearranged to support the five programs, including money approved in the current fiscal year by Congress.

The new strategic defense initiatives and funding profiles are:

Surveillance, acquisition, track and kill assessment—$366.5 million, $721 million, $1.5 billion, $1.9 billion, $2.7 billion and $3.3 billion in Fiscal 1984 through 1989, respectively.

Directed-energy weapons—$322.5 million, $489 million, $1 billion, $1.2 billion, $1.4 billion and $1.4 billion in Fiscal 1984 through 1989, respectively.

Kinetic energy weapons—$195.8 million, $356 million, $870.3 million, $1.3 billion, $1.5 billion and $1.7 billion in Fiscal 1984 through 1989, respectively.

Systems analysis and battle management—$82.7 million, $99 million, $137.5 million, $227 million, $260.1 million and $288.4 million in Fiscal 1984 through 1989, respectively.

Support programs—$23.5 million, $112 milliion, $270.8 million, $321.9 million, $453 million and $666.7 million in Fiscal 1984 through 1989, respectively.

Management of the five programs is being assigned to the "Office of the Secretary of Defense for top-level fiscal and technical management control," according to a memorandum to the service secretaries, chairman of the Joint Chiefs of Staff and directors of Defense Dept. agencies.

Funding proposed for the strategic defense initiatives clears the way for the Defense Dept. to complete its budget preparation for submission to the White House later this month. The services are still adjusting a number of weapons programs to fund the new initiatives. The Fiscal 1985 funding request will contain an additional $250 million above previously programed funding.

Combining the $991 million in the current fiscal year for the five initiatives with $1.8 billion in the Fiscal 1985 request brings the total to $2.8 billion to begin the new defensive programs, Defense Dept. officials said.

The Office of Management and Budget has informed Congress that overall defense spending in Fiscal 1985 through 1989 could be reduced by approximately $61 billion from earlier estimates. This would provide $305 billion in Fiscal 1985, down from the earlier estimate of $321.6 billion. Fiscal 1986 would be reduced by $9.6 billion to provide $346.8 billion, with Fiscal 1987 down by $10.5 billion to a level of $377.8 billion. Fiscal 1988 would be reduced by $11.2 billion to $413.1 billion, and Fiscal 1989 would be reduced by $12.9 billion to $450.7 billion.

Despite these reductions in overall spending, based on anticipated outlays and revenues, strategic initiatives are expected to be funded to meet the goals of a long-term research and development program plan by the Defense Dept.

The five broad technical areas are broken down into projects and tasks. "To execute the program, the projects have been assigned to a single service or agency, which is responsible for the overall management and coordination of all the tasks," according to the Defense Dept.'s strategic initiatives plan.

Program management includes:

Army—Surveillance and acquisition, track and kill assessment with terminal sensor programs and demonstrations. The service also would be responsible for all ground-based mid-course sensor programs and associated component technology, and data gathering. In the area of directed-energy weapons, the Army would handle device development and ground-based components related to free-electron lasers and neutral particle-beam devices. Conventional weapons development for the Army would center on ground-based terminal and mid-course interceptors, including advanced concepts. Systems concepts and battle management work by the service would be on mid-course and terminal systems

Air Force—Space-based sensor programs for boost-phase and mid-course surveillance and tracking, including component technology and data gathering. Directed-energy weapons development would be concentrated on space related devices and concepts. These would consist of chemical and excimer lasers, free-electron lasers for space basing and neutral particle-beam devices for use along with space optics. USAF is responsible for programs associated with space-based boost-phase systems, including survivability, lethality and subsystems such as power and launch vehicles.

Navy—Alternative approaches to laser and particle-beam weapons.

Defense Advanced Research Projects Agency—Technology programs associated with advanced space-based imaging sensors and other advanced technology. In directed-energy weapons, DARPA is responsible for short-wavelength laser technology, optics technology, particle-beam technology, acquisition, and pointing and tracking technology, including nuclear-pumped directed-energy weapons.

Defense Nuclear Agency—Programs defining nuclear backgrounds for optical and radar sensors, lethality and hardening programs.

The Defense Dept.'s management approach is to realign ballistic missile defense into the five broad areas or technical groupings in the Defensive Technologies Study Team, headed by former National Aeronautics and Space Administration head James C. Fletcher.

The strategic defense initiatives plan sent to the services and agencies in the Defense Dept. stressed "urgency in getting the program moving so that startup complexities can be resolved during Fiscal 1984. Also, it is understood that the President plans to devote a paragraph in the State of the Union message to the effect that the program is in place and working," according to a Pentagon memorandum.

The memorandum to the services said: "It is understood that there will not be a massive injection of new money to support these initiatives. The services and agencies will use existing funding for on-going programs but will probably expect to accommodate new and expanded programs within their existing funding ceilings for the most part—[although] some modest amount of new money may flow."

The Navy recognized this approach to directed-energy weapons development and did not fight hard to expand its role in initiatives. The Army Ballistic Missile Defense Command, however, has reorganized to accommodate the on-going and new programs. Changes also are expected in the Air Force organization for the defense initiatives.

"There will probably be a new civilian chief of strategic defensive systems in the Defense Dept., most likely reporting to the deputy Defense secretary," according to the Defense Dept. memorandum. "Ultimately, a new Defense Dept. agency may be created to manage the total program."

In addition to the $991 million in Fiscal 1984 and the $1.8 billion in Fiscal 1985, funding in the proposed plan for Fiscal 1986 is $3.8 billion, with almost $2 billion of that amount additional funding. In Fiscal 1987, the program total would be $5 billion, with $2.8 billion of that new funding.

Funding proposed for Fiscal 1988 is $6.2 billion, with $3.5 billion of that new funding added to the $2.7 billion previously programed. The Fiscal 1989 program total would be $7.4 billion, with $4.4 billion of that in added funding.

The strategic defense initiatives program is being funded to provide a broadbased technology development effort in the near term aimed at reaching a decision point on weapons development in the early 1990s, with deployment in the year 2000 and beyond.

The plan calls for multiple layers of defensive weaponry, technical demonstrations, survivability and innovation, according to Defense Dept. presentations to Congress. The plan calls for development of destructive mechanisms for defense that include:

Pulsed lasers—X-ray and excimer devices to deliver a high impulse or shock to a missile to break or blow a hole in it and cause structural collapse of the booster.

Continuous wave lasers—Free electron, excimer, hydrogen/deuterium fluoride laser devices designed to place the beam on the target until a hole is burned through it, then switch to another target.

Continuous particle-beam weapons—Neutral particle-beam device to destroy internal weapon components.

Mass accelerator—Kinetic energy rail gun to accelerate small homing hit-to-kill nonnuclear vehicles.

Self-propelled missile—A miniature homing vehicle using infrared sensors to sense radiation on incoming reentry vehicles, home on and destroy with a hit-to-kill vehicle.

The plan presented to congressional committees by the Defense Dept. states that the initiatives do not constitute a change in long-standing policies of deterrence. It

adds, however, that effective defenses against ballistic missiles have potential for increasing deterrence and stability. The initiatives would provide a significant reduction in the utility of a preemptive attack and reduce or eliminate effective counterforce options when combined with air defenses.

The incentive to add multiple independently targetable reentry vehicles to ballistic missiles also would be decreased with an effective defense, the Defense Dept. plan said.

The strategic defense initiatives, according to the Defense Dept., would provide a hedge against a Soviet program that includes:

"Upgrading the world's only active ballistic missile defense system."

"Pursuing research and development on a rapidly deployable antiballistic missile system."

"Pursuing advanced defensive technologies, e.g., lasers."

The Defense Dept. told Congress that the USSR has "an improving potential for large-scale deployment of modernized antiballistic missile defenses beyond the 100-launcher treaty limits. Should the Soviets abrogate the ABM treaty, widespread ABM deployment to protest important installations in the USSR could be accomplished in the next 10 years because of the size and vigor of their research and development programs."

The report to Congress said the Soviets have been working as long as and more extensively than the U.S. on directed-energy weapons—laser, radio frequency and particle-beam technologies, with emphasis on laser weapons.

The USSR, the report said, has built more than six large research and development facilities and test ranges for these weapons and has an "estimated 10,000 scientists and engineers associated with the development of laser weapons. They are developing chemical lasers and have continued to work on gas dynamic and electric discharge lasers.

"They are also pursuing related laser weapons technologies such as efficient electrical power sources and are pursuing technologies to produce high-quality optical components.

"They [the USSR] have developed a rocket-driven magnetohydrodynamic generator which produces 15 megawatts of short-term electric power—a device that has no counterpart in the West," according to the report.

[From Science, Apr. 6, 1984]

WEAPONS BUREAUCRACY SPURNS STAR WARS GOAL

CONTRARY TO POPULAR BELIEF, THE PENTAGON DID NOT ENDORSE REAGAN'S VISION OF A MISSILE-FREE WORLD

A year ago, President Reagan announced on national television that he was "launching an effort which holds the promise of changing the course of human history," a long-term program of scientific research intended to eliminate the threat posed to the civilian populations of the United States and its allies by Soviet strategic nuclear missiles. The idea, which came as a complete surprise to all but a few high-level Administration appointees, was quickly put before two panels of prominent weapons scientists, who gave it their hearty endorsements in two classified reports delivered last fall.

This, at least, is the impression that the White House has sought to convey through a series of press briefings, interviews, and formal statements about the idea, which is generally known as the "star wars" proposal. As presidential science adviser George A. Keyworth, II, told *Science* last November, "I think truly the most important thing that happened in the reports is that a bunch of people from very different perspectives concluded at the end that just what the President said, his objective, was feasible."

In fact, the conclusions of the reports fall considerably short of a hearty endorsement, and—as it became clear in recent congressional hearings on "star wars"—there remains considerable skepticism, even within the defense bureaucracy, that the President's idea is sensible, much less attainable. A feud on the subject between Reagan's technical advisers in the White House and those in the Pentagon has now broken into the open, with one group favoring the goal of total population protection and the other largely dismissing it. As a result, prospects for congressional approval of the costly program have dimmed considerably. Despite recent attempts in some quarters to paper over the differences, dissension is rife and confusion about the program's goals and practically remains widespread.

Although some high-ranking Pentagon officials now deny it, President Reagan's idea was clearly to devise a military system that would protect the public from all Soviet intercontinental ballistic missiles. As Secretary of Defense Caspar Weinberger said shortly after Reagan's speech, "The defensive systems the President is talking about are not designed to be partial" and "What we will try to do will be to develop a system that is so reliable that it will, in effect, render impotent *all* of these nuclear missiles" [emphasis added].

The clear implication—and chief political attraction—of Reagan's proposal is that such a defense would provide an alternative, not a complement, to offensive nuclear weapons. As Reagan explained at a press conference, he wants a system that will enable some future president to tell the Soviet premier, "I am willing to do away with all my missiles. You do away with yours." Keyworth in particular has used this as a selling point, telling a meeting of the Armed Forces Communications and Electronics Association last October, for example, that the President seeks to abandon the doctrine of mutual assured destruction in favor of "a new stability based on, as he called it, rendering nuclear weapons obsolete."

The difficulty is that this goal, though laudable, is generally thought by most experts to be completely unattainable. As Ashton Carter, a research fellow at MIT who consults on ballistic missile defense (BMD) for the Pentagon and the Office of Technology Assessment, notes in a book on the topic published this spring by the Brookings Institution,[1] there is a broad consensus within the technical community that the prospects of defending people from nuclear missiles are "so remote as to be of no practical interest." There is, he says, "no extrapolation from present BMD capabilities and costs that could enforce near-perfect, high-confidence protection against a determined opponent. . . . Mutual assured destruction, seen as a condition of technological life rather than a chosen doctrine, seems unavoidable."

Despite White House assertions to the contrary, neither of the two "star wars" reports prepared at its request explicitly states that a foolproof defense of the general public against Soviet missiles is achievable, permitting the eventual abandonment of offensive weapons. One report, prepared by a panel of 12 weapons analysts under the direction of Fred Hoffman, goes so far as to say that even a slightly imperfect defense, or one that permits a few Soviet warheads to reach U.S. or allied territory, "may prove unattainable in a practical sense against a Soviet effort to counter" it. The report, which has not yet been officially cleared for release, dwells instead on the virtues of enhancing deterrence against a Soviet attack with a *mix* of offensive and defensive weapons, and speaks enthusiastically about the attractions of limited systems designed expressly for the defense of weapons, not people. Specifically, it recommends pursuing three options as "intermediate" steps on the path to a more complicated, but still imperfect, ballistic missile defense: a system capable of defending against short-range tactical nuclear missiles; a system capable of defending only military command and control centers against a limited nuclear attack; and a space-based system capable of destroying a limited number of Soviet Union's missiles within seconds after their launch.

An unclassified summary of the other report, which was prepared by 50 experts in BMD technology under the direction of former NASA administrator James Fletcher, says only that additional research and development are necessary before a decision can be made "on how to begin an engineering validation phase . . . that, in turn, could lead to an effective defensive capability in the 21st century." Although the term "effective" is never precisely defined, the report indicates that at best, a complex BMD system could not keep all Soviet warheads from striking U.S. territory. Edward Gerry, a former director of the strategic technology office in the Defense Advanced Research Projects Agency who directed a key Fletcher panel subcommittee, explained in recent congressional testimony that the group "recognized from the outset that a completely leakproof defense is certainly impractical if not impossible." In short, it differed not only with Weinberger and Keyworth but with the President as well.

The issue is significant because a massive Soviet attack against anything but a perfect ballistic missile defense would still cause widespread destruction of cities and massive civilian deaths in the United States. The Fletcher panel report claims, for example, that a BMD system composed of three successive layers, each of which was 90 percent effective, would allow penetration by only 0.1 percent of the attacking warheads. Skeptics within the scientific community, such as Hans Bethe, Kurt Gottfried, and Richard Garwin, say that such effectivess cannot be achieved. Even if it was, dozens of nuclear warhead would still strike U.S. territory under the maxi-

[1] *Ballistic Missile Defense*, Ashton B. Carter and David N. Schwartz, Eds. (The Brookings Institution, Washington, D.C. 1984).

mum Soviet threat envisioned by the panel. Everyone agrees that as long as such a threat exists, it can be deterred only by the threat of retaliation with offensive nuclear weapons. This is why Richard DeLauer, the Pentagon's top scientist, and in testimony on 8 March before the Senate Armed Services Committee that he could not envision any ballistic missile defense system that would eliminate the need for offensive missiles. "Does anyone?" asked Senator Sam Nunn (D-Ga.). "Not in the foreseeable future," DeLauer replied.

The danger of deploying both offensive and defensive strategic weapons simultaneously was specified by Reagan in his initial "star wars" announcement. "I clearly recognize that defensive systems have limitations and raise certain problems and ambiguities," he said. "If paired with offensive systems, they can be viewed as fostering an aggressive policy and no one wants that." The basis for this concern is that even a somewhat imperfect missile defense might be regarded as militarily useful in the face of a drastically diminished Soviet threat—diminished that is, by a preemptive U.S. attack. As implausible as such an attack may be, construction of such a defense would at best create extreme anxiety in the Soviet Union, and at worst evoke an attack to keep it from becoming operational, an attack that, as DeLauer points out, "is not hard if you are deliberate about it."

Unable to vouch for the technical feasibility of the perfect missile defense envisioned by the President, both the Pentagon and the panels of BMD experts have resorted to a recitation of old and familiar arguments on behalf of an imperfect defense: Oriented to the protection of offensive weapons, for example, it could enhance deterrence either by limiting the "military utility" of a massive preemptive attack or by increasing the number of Soviet warheads required to achieve a given amount of destruction. In the face of a much more limited attack including one launched from a country other than the Soviet Union, such a defense might even be able to protect population centers. And in the unlikely event of an all-out war, an imperfect defense might keep the number of civilian deaths down to what many weapons officials consider to be a relatively small number. "Faced with the prospect of losing 180 million people versus 10 million, it makes sense to try for the latter," remarks Major Peter Worden, a special assistant for BMD in the Pentagon's research and development office.

None of this has gone down easily at the White House, where Keyworth in particular has been pressing for research on a total defense of population centers. "The President was not talking about improving warhead exchange ratios; he was talking about a change in our defense posture," Keyworth told Science last fall. "We're not trying to preserve nuclear deterrent in this program, we're trying to move away from reliance upon the nuclear deterrent." Another White House official familiar with this issue, who asks to remain anonymous, now says that "as politely as I can put it, these guys at the Pentagon are incorrect. It is most specifically not our intent to advocate defenses solely for offense military systems." The official acknowledges, however, that such defenses might be more feasible in the near-term and insists that they "would eventually evolve into a multifaceted capability to defend the people as well."

Keyworth himself stresses that "Hoffman, DeLauer, and myself all agree on the need to produce a path that will reduce our reliance on nuclear weapons, and any step you take to develop defensive weapons reduces the military usefulness of offensive ones. My definition of a perfect or ideal system is one whose effectiveness is so great that no enemy would conceive of attacking it. Now whether that means 99.9 percent effectiveness or something less depends on the type of weapons in his arsenal. What does rendering nuclear weapons obsolete mean? Nuclear weapons are so devastating that they will never be truly obsolete; they will continue to exist and be feared. But the world would be a lot safer if they were no longer so heavily relied upon."

Confusion about the program has considerably harmed its prospects in Congress. The Administration has requested an appropriation of $1.77 billion for work on the President's Strategic Defense Initiative during fiscal year 1985, a 78 percent increase over the budget for 1984. In 1986, the budget is scheduled to jump 114 percent, to $3.77 billion. The entire program, which is intended to facilitate a decision in the early 1990's about whether and how a missile defense should be constructed, is expected to cost at least $25 billion. And this is merely a downpayment, as the BMD itself is expected to cost hundreds of billions of dollars more.

During recent congressional hearings, Senators Barry Goldwater (R-Ariz.) and Sam Nunn indicated that these costs might be more palatable if the program truly offered a chance to eliminate the threat of nuclear missiles. "It is one thing for the American people to believe they are supporting a program based on doing away with offensive weapons," Nunn said. "When [they] wake up and find out that is not

what we are going to be doing, [that the Administration is] going for both offensive and defensive, they will have a change of heart," Goldwater noted that "we are faced, in my opinion, with a threat far more destructive than anything that Russia might throw at us in missiles, and that is our deficit." He said that it was his "strong feeling" that Congress would never fund such a costly project.

The initiative's fate is far from settled, but the debate thus far has clarified a key issue. A total defense of the population and the elimination of offensive weapons, the goals that initially caught the President's attention, are now acknowledged to be infeasible, even by the military bureaucracy. As a result, policymakers can turn their attention to the same questions that bedeviled Washington in 1968 and 1969: Is it destabilizing to deploy a system designed to protect offensive nuclear weapons? Does it make sense to defend against the possibility of a limited nuclear attack? Will a limited nuclear attack ever occur? What about the Pentagon's existing relatively inexpensive BMD effort—a Navy program designed to reduce the noise emitted by missile-carrying submarines, so as to prevent their detection and destruction in a global conflict? There is a long list of relevant questions, each worthy of earnest debate.—R. Jeffrey Smith

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[From Science, Apr. 6, 1984]

STAR WARS PANELS HIGHLIGHT UNCERTAINTIES

(By R. Jeffrey Smith)

"We took an optimistic view of newly emerging technologies and . . . concluded that a robust, multilateral ballistic missile defense [BMD] system can eventually be made to work," says James Fletcher, in describing the conclusions of the Defensive Technologies Study Team that he chaired. But neither his group nor a second panel chaired by Fred Hoffman was able to say exactly when such a system would work, how well it would work, or how much it would cost. And both listed enough political and technical uncertainties to satisfy even the most ardent BMD critics.

The Fletcher panel, for example, noted that the deployment of directed energy weapons in space—a key element of most BMD concepts—"not only requires significant technical advances but also poses difficult policy issues which need to be addressed." It also said that the need to protect such weapons from preemptive attack "is an especially critical issue whose resolution requires a combination of technologies and tactics that remain to be worked out." Similarly, the Hoffman panel noted that the first two layers of a full-scale defensive system "may present problems of both vulnerability and high sensitivity to attack size." It added that such a system "might decrease stability" if it was paired with offensive nuclear weapons that were vulnerable to a large Soviet attack.

In an interview with *Science,* Fletcher said that the members of his group all felt that the technical problems could eventually be overcome. (Richard DeLauer, the Pentagon's top scientist, is more skeptical. Last November, he said that the challenges are equal to or greater than those posed by the Manhattan Project in each of nine different research areas.) "But the question is: can it be done for a reasonable cost? I think the answer to that will be unresloved for a long time," Fletcher says. He cautions that even the best ballistic missile defense will be incapable of defending the total U.S. population. "Total is one thing, substantial is another," Fletcher says. "What you want to do is minimize the casualties. There is no such thing as a nuclear umbrella." Hoffman agrees. "If what you want defenses to do is to protect the bulk of our population against an attack by a large Soviet force that has the objective of destroying our population, then you would need everything [in a BMD system] to work," he says. "Even as a nontechnician, it seems to me that the likelihood of this happening is small."

The Hoffman panel report, which was prepared by a group of weapons industry representatives and established Pentagon consultants, emphasizes that less complex defensive systems, primarily intended to protect military assets, may be more practical as well as more useful. "You have to ask yourself where attacks on cities would rank in the actual [Soviet] war plans," explains Hoffman, an affable, soft-spoken economist with 30 years of experience in strategic weapons analysis, who is now director of Pan Heuristics in Marina del Ray, California. "That's not what they would primarily be interested in. This raises the question: how do you deter an attack? One way is by convincing an opponent he'll suffer terrible damage in response; another is to convince him that he simply won't achieve the objective that

he wants." If military assets are the primary objective, their protection puts the biggest obstacle in the path of an attack, he says.

A defense against a limited nuclear attack would be particularly valuable in the event of a conventional conflict between U.S. and Soviet forces in Europe, Hoffman argues. If the Soviets wanted to block U.S. equipment and troop reinforcements, they might attack a limited number of U.S. ports and airfields, believing that the President would choose to end the conflict rather than retaliate. By raising the price of a successful limited attack, a BMD system would reduce the prospect that it would remain limited, he says. As a result, the attack would never occur. It is reasonable to ask, however, whether such an attack by the Soviets is likely in the first place, and how the Soviets could believe that the United States would fail to retaliate in the face of hundreds of thousands of deaths and widespread coastal destruction.

Asked why a defense of U.S. military assets would not be destabilizing, Hoffman responds that the Soviets probably don't fear a first-strike by the United States. "We've been through periods when on the usual criteria of stability, [the Soviets] should have been attacked and weren't. Look at their behavior during the period [in the 1950's and early 1960's] when they were subject" to U.S. strategic superiority, he says. "Was it recessive, did they never give us any trouble, did they always behave obsequiously? Not quite." He also notes that "neither side will ever be confident" how well a ballistic missile defense will work. As a result "I do not believe they would impute to our defenses a degree of perfection that says, 'This is going to leave the United States in a position to liquidate the Soviets with impunity.'" Consequently, it seems unlikely that they would attack the United States to prevent the deployment of such a system.

Hoffman agrees, however, that any predictions about the new strategic defense initiative must be hedged by uncertainty. As the Fletcher panel concluded, "the ultimate utility, effectiveness, cost, complexity, and degree of technical risk in this system will depend not only on the technology itself" but also on the Soviet Union's ability to develop similar technology and limit its offensive forces.

Senator PRESSLER. At this time I yield to Senator Percy.

The CHAIRMAN. Thank you, Senator Pressler, and thank you, Senator Pell.

Dr. Keyworth, I would like to turn to page 12 and the statements that you made there. I will just quote a couple of sentences: "While I see absobutely no need to violate any provisions of existing treaties while we investigate these options, I am very leery of entangling ourselves in further treaties until we know more."

Is this the real reason that the administration refuses to enter into ASAT negotiations—not verification as the administration report suggests—because if this is true, then it would mean that we really could not get into these negotiations for at least 5 years?

Dr. KEYWORTH. No, no. Senator Percy, the reasons have been clearly stated in the President's policy that was submitted to Congress on March 31, and I endorse those views entirely. I was simply addressing the Strategic Defense Initiative as a research project that I believe is extremely important to our ultimate posture and strategy and future options, and that those options should not be constrained.

So I guess I was addressing the Strategic Defense Initiative specifically. And if you move it into the context of the committee's concerns about ASAT, I entirely support the policy and the exact comments that Richard Perle has been making about verifiability. Our concern is that we have not achieved or found an approach or a potential treaty that holds significant merit.

The CHAIRMAN. Dr. Gerard Smith was unable to testify in person today, but has sent in testimony which I would ask be incorporated in the record, Mr. Chairman, at this point.

[Mr. Smith's prepared statement follows:]

PREPARED STATEMENT OF HON. GERARD C. SMITH

Mr. Chairman, members of the Committee, I thank you for inviting me to testify on the implications for the 1972 Anti-Ballistic Missile (ABM) Treaty of the Strategic Defense Initiative (SDI). I submit this statement as an individual and not as a spokesman for the Arms Control Association, of which I am Chairman.

I believe there is now in prospect a dangerous shift in U.S. strategic thinking which threatens further to accelerate the nuclear arms race. It was initiated by the President's Strategic Defense Initiative. The SDI would be a highly costly effort to render Soviet offensive missiles impotent by building an impenetrable defensive shield which is not banned by the most significant Soviet-American arms control agreement, the 1972 Anti-Ballistic Missile Treaty.

This treaty banning nationwide ballistic missile defenses was based on recognition by the superpowers that such a system could only weaken the deterrent effect of their respective retaliatory forces and by undermining the strategic balance increase the risk of nuclear war. In agreeing to the ban both nations endorsed the view that nuclear war is not survivable. By restraining destabilizing new technologies, the Treaty effectively deterred a costly and security-compromising combined competition in both offensive and defensive systems. The ABM Treaty might be considered a mutual and verifiable freeze on defensive deployments that has enhanced American security.

What is wrong with trying to develop defenses? After all, it is their purpose to destroy missiles and not people, to protect rather than to threaten. True, but intent and effect are wholly different. Nuclear weapons have blurred the distinction between offense and defense.

For years American and Soviet security has involved a condition of mutual insecurity—like two scorpions in a bottle each unwilling to sting lest it in turn be stung to death. If one side came to believe that it was sting-proof it could be tempted to attack. Therein lies the gravest danger in the nationwide defense systems envisioned by the President. I say "systems" advisedly because he has in mind a Soviet defense as well as an American. In fact, he would have us transfer our defense technology to the Soviets!

You may be sure that U.S. efforts to build defenses will be matched by the Soviet Union and then our concern about being attacked will mount and crisis stability decline. This is no abstract theory; it is based on lessons drawn from recent history. In the late 1960's the Soviets deployed the "Galosh" ABM system to defend Moscow. They already had in place a large anti-aircraft system. The main justification for the large subsequent increase in U.S. offensive strategic warheads (MIRV's) was to assure a retaliatory capability to penetrate the new Soviet defenses. American MIRV's were quickly followed by similar Soviet systems. As a result, both nations now have to live with this destabilizing threat to their land-based missiles and have suffered a substantial erosion of their national security. Deployment of a missile defense system would have similar consequences. Each superpower would strive not only to match the ABM system of its rival but to find ways to penetrate it.

Contrary to Administrative assertions that the SDI is consistent with the provisions of the ABM Treaty, it is clear that research and development programs now proposed by the Departments of Energy and Defense have a different aim. Their trajectory and momentum puts them on an inevitable collision course with the Treaty which is why "Star Wars" proponents speak of amending the Treaty to allow the very nationwide defenses it was designed to prohibit. This would be like amending the Volstead Act to permit the sale of alcohol. Only the prospect of a totally leak-proof defense would warrant abandoning our present retaliatory weapons and strategy. This is the vision President Reagan held out to the American people. While our leaders would not agree to a complete ban on strategic nuclear weapons because they do not trust the Soviets, and correctly so, they held out this prospect of offensive weapons disappearing from the face of the earth once new defense systems have neutralized them. This strikes me as having been a cruel illusion to put in the minds of the American people.

Although the President and the Secretary of Defense seem genuinely committed to the idea that eventually the superpowers can foresake offensive weapons, it is apparent that many supporters of this initiative have a less idyllic future in mind. Rather they see a time when America's superior technological and economic strength will permit us to have both offensive forces and sufficient defenses to regain a measure of strategic superiority we held in the past (a condition the President expressly labelled as dangerous). These advocates are aiming for defenses to supplement and strengthen offensive forces, not as a substitute for them. They do not see defensive systems as rendering offensive forces obsolete but as adjuncts for

limiting damage in the event of nuclear hostilities. Testifying before the Senate Armed Services Committee several months ago, Deputy Under Secretary Richard DeLauer stated that he could foresee no defensive system that would preclude the need for the United States to retain offensive missiles. While the President has repeatedly said there can be no winners in a nuclear war, the implication of the SDI and the necessary conclusion drawn by Moscow is that the United States seeks a nuclear war-fighting capability.

It is an especially pernicious rationalization for "Star Wars" proponents to argue that ballistic missile defenses will have a beneficial impact on arms control. It is curious to read statements by Administration officials that once we have demonstrated a national resolve to deploy huge defenses the U.S.S.R. will begin to take seriously our present proposals to reduce offensive arms, as if a demonstrated intention to terminate one form of arms control would encourage the adversary to agree to another. The "build-up in order to negotiate down" approach of recent years has only induced Soviet intransigence. Its predictable result has been more nuclear weapons and less security.

We already have negative reactions from our allies who see superpower defenses as inconsistent with their security. When the U.S.S.R. no longer need fear American missiles, gone will be the deterrent to Soviet attack on Europe. And Soviet defenses will render impotent French and British nuclear forces. It would be difficult to imagine a more divisive issue to present to NATO.

Almost two decades ago the prospect that the superpower military rivalry would spill over into outer space prompted negotiations to ban nuclear weapons from space. One of the techniques now under consideration to defend against ballistic missile attack involves nuclear weapons in space. It thus seems probable that the Outer Space Treaty would be another casualty of the "Star Wars" program. And since it is quite unlikely that the Pentagon would be willing to rely on an untested defensive system, there would arise requirements for testing nuclear weapons in the atmosphere and in space, thereby violating the 1963 Limited Test Ban Treaty.

Still another example of the prejudicial impact of "Star Wars" on arms control possibilities has been its effect on the resumption of the Anti-Satellite (ASAT) negotiations. Since the United States depends on space satellites for its military operations on earth more than the U.S.S.R., one would suppose that we shared the Soviet's interest in banning ASAT systems. The Soviets have even tabled a draft treaty which experts believe forms the basis for serious discussion. That we have shown no interest in resuming talks and have begun to test a U.S. ASAT weapon lends credence to the view that one reason why the Administration is eager to push ahead with the ASAT program is because of its potential "Star Wars" applications.

I have concentrated largely on the damage to arms control that would result from this move toward strategic defenses. But I would also like to make a few brief observations about its technical feasibility. I claim no expertise in this field, but having been acquainted for about a third of a century with leading nuclear scientists and engineers, I prefer the judgment of those who conclude that "Star Wars" is wishful and dangerous thinking.

Unlike other monumental scientific challenges which have been successfully met, such as putting a man on the moon, ballistic missile defense is not a static problem. Any conceivable "Star Wars" configuration could be overwhelmed by counter-measures. In addition, the system envisioned in "Star Wars" aims only to defend against ballistic missiles, not bombers or cruise missiles. After spending hundreds of billions of dollars we would be left with an imperfect defensive system that will supplement but not supplant offensive systems. Can't America's security dollars be more prudently spent?

I have offered my views on the value of the ABM Treaty and the danger of it being either emasculated or simply terminated as a consequence of the Strategic Defense Initiative. The ABM Treaty is the best weapon we've got for bringing under control one of the driving forces behind the nuclear arms race. For more than a decade the Treaty has prevented an arms race in defensive weaponry and contributed to maintaining the peace.

Research and development as permitted by the ABM Treaty should be continued as a hedge against possible Soviet breakout from the Treaty, but U.S. programs looking to American breakout should not be allowed by the Congress.

The CHAIRMAN. I will just read one paragraph from Mr. Smith's statement:

I believe there is now in prospect a dangerous shift in U.S. strategic thinking which threatens further to accelerate the nuclear arms race. It was initiated by the President's strategic defense initiative. The SDI would be a highly costly effort to

render Soviet offensive missiles impotent by building an impenetrable defense shield which is now banned for the significant Soviet American arms control agreement, the 1972 Anti-Ballistic Missile Treaty.

I know that you have quoted, Dr. Keyworth, from the President's March 23 speech of last year. The last sentence of your quotation indicates, "This could," that is, the SDI, "could pave the way for arms control measures to eliminate the weapons themselves."

We do not disagree with any of this, I believe, because it is the President's stated policy, and it was this policy that was adopted last year by this committee in an overwhelming vote, that said our goal should be the total elimination of nuclear weapons. that is our objective. The question before us today is does SDI really move us in that direction, and that is what we are earnestly together trying to seek an answer for.

As I understand the problem, Soviet missiles are vulnerable during their first minutes of flight, and intercepting these missiles is the key to any effective multilayered, space-based defense system. Yet, we had testimony in 1981, as I recall, from a top Defense Department official, who testified that since there would not be appropriate time to consult with the appropriate military or political officials, authority to fire would really have to be delegated to computers.

How deep a crisis do you think we would be plunged into if a computer-controlled U.S. space defense system mistakenly destroyed a manned Soviet space launch?

Dr. KEYWORTH. Senator, in an era when realistically we are forced to seriously consider the option of launch under attack, then I consider the threat of having to respond via modern data processing to the attack—not of a spacecraft but of a Soviet launch against the United States—to be a stabilizing change, not a destabilizing change. And I think the example of shooting down a spacecraft is to pay little attention to the immense progress in technology that is occurring.

You simply must develop a system where that opportunity is negligibly small.

The CHAIRMAN. Let me just reference the fact that we have had an alarming number of documented computer failures at the North American Air Defense Command [NORAD]. I happened to be there years ago, visiting with a group of business people, and that was years ago when I was in business. I was there with the then-president and chairman of the board of IBM, Tom Watson, and I believe Bob Galvin of Motorola was with us when a false signal actually came in.

A national publication later described that incident, and none of us could even recognize the chaos and confusion that we saw with our own eyes as against the article which portrayed it as an incident that we could somehow handle.

Would you be comfortable in taking men completely out of the decision loop in view of the number of alarming false signals that we have had at NORAD? Isn't there just too great a probability of our initiating hostilities by error?

Dr. KEYWORTH. Senator Percy, the reason why, in spite of a number of glitches over the years, as you have described, we have not yet had any disastrous consequences in terms of initiating a

nuclear exchange, is because we have built in so many, many cross-checks and mechanisms to prevent that.

Clearly, in this system, the same thing would have to be done. We have a vast capability today, technological capability, that we did not possess 10, let alone 20, years ago. I believe that the system could be made absolutely safe. But I especially must emphasize here that we are not talking about the initiation of a nuclear exchange, and that is the very stabilizing result that we are trying to achieve by introducing defense into our strategic posture to remove the threat of initiating nuclear war.

What we are talking about is defending against an attack against the United States.

The CHAIRMAN. Well, putting it another way, taking into account the state of the art now and what we contemplate as the state of the art, my question would really be: Would you sleep well at night knowing that we have put all our eggs in one basket and that we had delegated responsibility for strategic deterrence to computers, actually?

What if our self-contained space defense system were to fail to respond to an actual Soviet attack? Could we trust it not to do so really?

Dr. KEYWORTH. Senator, none of us has ever proposed, nor do I think any of us believe that we are describing or discussing here some magical shield under which we can live with no concerns. We are talking about an element of our defense posture and a gradual change in strategy, a strategy in which ultimately the Strategic Defense Initiative will be one single component. To focus just upon the Strategic Defense Initiative, I do not believe you will have man completely out of the loop. You will have a decision that will have to be made in a compressed period of time. Therefore, data processing will play a very high role.

But just as we have today so-called DEFCONS [defense conditions] we will have them at that time, and we will have, presumably, a continued heightening of awareness and sensitivity and presumably tension.

The CHAIRMAN. Most experts do agree that, even with a space-based ballistic missile defense, the the United States would have to retain robust strategic retaliatory forces. This means, according to experts, that we will still need weapons like the MX, the B-1, Trident, Midgetman, and so forth. If we cannot scrap our offensive weapons, where would we find the hundreds of billions of dollars—and I know there is some disagreement about how much it would cost, but we have other authorities that really liken this to five Apollo programs and so forth, and talk in terms of trillions of dollars—where would we find the money to deploy an effective space-based defense if we still had to maintain these other systems?

Dr. KEYWORTH. Senator, there will be many steps in the decision processes down the road, and I have tried to emphasize that point in my testimony. We are providing options, options for Members of Congress, options for future Presidents. At present when I hear these constant estimates of $1 trillion, $10 trillion, $100 billion or $10, I always ask, "What is it that is to cost that amount of money?" No one can at this time define that unknown pronoun.

I believe that the amount of money that we are really discussing today is entirely reasonable within the Department of Defense R&D budget which describes these critical options for the future. I think it is a complete waste of time to discuss the magnitude of ultimate commitment when we are so many steps away from being able to make deployment decisions, let alone even later-stage research and development decisions.

The CHAIRMAN. Let me just go back a few weeks ago to a statement that General Bernard Rogers made. He is a man for whom I have a tremendous regard as Supreme Allied Commander in Europe. He made the statement that our situation against Warsaw Pact countries with respect to conventional weaponry is such that if an overt act were made, such as has been made in Afghanistan, such as was made years ago against Eastern Europe, and might now be made against Western Europe, he would have to call for the use of theater nuclear weapons very, very early. And he therefore now calls for another increase and a stronger—and I have always supported that—a stronger effort on conventional weaponry.

What is the danger that funding for conventional forces may necessarily have to be cut if we go into this kind of a program when we can see already there is really no inclination on the part of the Congress to fulfill the President's present request, either last year or this year, for the full amount of increase that he has asked for in conventional weaponry.

Dr. KEYWORTH. Senator Percy, clearly we are all laboring under the very real and very clear pressures of the deficit and determining the priorities in defense. Looking at General Rogers' particular concerns, which I think I very much share with you, that is exactly what motivated the President to his March 23 speech of a year ago—a perception of unacceptably low stability in the future and perhaps at the present time. General Rogers might call it a low nuclear threshold, unacceptably low.

I have tried to emphasize in my testimony that the first goal that we have prior to achieving of the ultimate goal of reduced reliance upon nuclear weapons is to improve stability by removing the opportunity for preemption from both sides and placing both sides, in each other eyes, in the position of reliance upon deterrence. I think that is General Rogers' objective. I think his objective of raising the nuclear threshold in Europe is entirely consistent with the goal of stability that is achieved by incorporating defense into our present purely offensive posture.

The CHAIRMAN. I have one last question if my colleagues will bear with me for a quick answer.

I have said so many times in this room that I have been so much more concerned, as I think all of us are more concerned, about the possibility of a nuclear war occurring from some regional crisis that occurs, rather than just as a bolt out of the blue with a Soviet missile attack.

Wouldn't cutting our conventional forces, if we had to cut them in order to go into this kind of program, invite Soviet aggression against our friends or allies and, hence, make nuclear war even more likely?

Dr. KEYWORTH. Senator, I would certainly subscribe to one thing. I would advocate no cut, and I would advocate even an increase in our conventional forces. I also believe that the research and development program that we are discussing at this stage is no threat at all to the health and progress of our conventional modernization program.

The CHAIRMAN. Thank you very much.

Senator PRESSLER. Senator Pell.

Senator PELL. Thank you, Mr. Chairman. I have three questions, but first I would like to make one point. I will address Mr. Perle.

My recollection, being on this committee at that time, was that when we MIRV'd, that is, made the decision to move ahead and MIRV, we did make an offer, as you pointed out, to the Soviets, but it was a nonstarter of an offer. It was after we had tested, but before they had—we called for onsite inspection which we knew they would not accept.

I think if you would think back and bear with me, you would agree with me that we did not really think of it as a very genuine offer.

Mr. PERLE. Senator, my recollection is that after considerable study, we came to the conclusion that without some form of onsite inspection, we could not have sufficient confidence that the Soviets would not deploy MIRV's, and so we felt we had no choice but to put forward a proposal that would be verifiable.

Now, it is true that we had already had some very limited number of tests. I think the situation is analogous to the ASAT area now; that is, the Soviets have already completed their test program, and they now have a working, operational ASAT.

That, evidently, has not discouraged some Senators from proposing that we nevertheless try to negotiate a ban. It seems to me the situation that some of you are suggesting we should be in is the situation we were proposing the Soviets should accept with respect to MIRV's.

But I believe it was a genuine effort to find a verifiable arrangement, and I frankly do not recall anyone arguing otherwise at the time. Perhaps Senator Pressler can identify the people he had in mind that said MIRV was going to give us some unalterable advantage. That was not the motivation behind the MIRV program at all. And I think there were very few serious officials who believed that the Soviets were not then actively working on a MIRV program and would not achieve a MIRV program.

Senator PELL. Thank you very much. I think our recollections are a little bit different, and I think if you would go back to Gerard Smith's book, who was I think leading the negotiations or very much involved at the time, you will see that we have a discrepancy in view here, but we are talking about events of 15 years ago, and institutional memories do suffer and there is not too much of it around. But that is my recollection. That definitely differs from yours.

Now, last summer, I was with a group of Senators, and we had quite a long discussion of the Soviet leadership with Mr. Andropov. And at that time, he said that the Soviets were willing to dismantle existing ASAT's and ban new ones. And as you know, some fear the Soviets would not admit they have their system, and thus

would be unwilling to dismantle it. Well, by the very fact of making the offer, they obviously admit that they have the system.

I would like to address this question, I guess, really to Dr. Keyworth. Do you believe the Soviets are prepared to admit they have a system and are prepared to dismantle it?

Dr. KEYWORTH. I certainly believe the Soviets are prepared to admit they have the system, because we are each aware of the other's interests and capabilities in this area, to a reasonable extent. As far as projecting whether they are willing to abandon it, I certainly cannot. I think it is dangerous to make the assumption. I think that is why we emphasize a reasonable verifiability requirement.

The Soviets did not accompany their proposal, their general proposal, with any specifics on how we could be certain that they would conform and how they could be certain that we would conform. That is the issue that we have emphasized in the President's policy.

Senator PELL. I would add that I went back to Mr. Andropov three separate times afterward on this question of verifiability. The impression he gave to me was that there would be no real problem with verifiability if we got down to the negotiating stage. Therefore, wouldn't it be better to start negotiating and seeing?

Dr. KEYWORTH. Well, Senator, I am not an expert on arms control negotiations, but I am not the least bit surprised that Mr. Andropov made that suggestion. Nevertheless, the suggestion does not negate the overriding concern at the outset for coupling those discussions with some means by which we can insure each other that there is some reasonable degree of compliance.

Senator PELL. But isn't it important to at least get into a negotiation and then see on whose back the cat will fall on the question of verifiability, but if Andropov came back as we did three times on this question of accepting verifiability, why not put him to the test? Why do we have this feeling now that we will not deal with him? He made a proposal, and it was made at the United Nations later on, to the effect that they would dismantle their system and engage in a moratorium. Obviously, we are not interested in a moratorium because they are ahead of us, but the dismantling is to our advantage.

Why not engage in negotiations? Why is the administration seeking to negotiate all the fringe issues—MBFR, chemicals, and different things of that sort—but not willing to get down to the heart of the matter or the guts of the matter?

Mr. KEYWORTH. Senator, first, I think Richard Perle should comment here. But I would just say from first principles that I think each side should enter the negotiations with sincere positions. I would only contend that a position on Mr. Andropov's part that involved an objective, with no attention to the very critical and, I contend—not second order but first order—issue of convincing each other of conformity is not a sincere approach to an arms control negotiation.

Senator PELL. My time is rapidly expiring, so please abbreviate your answer as much as possible.

Mr. PERLE. Senator, the Soviets have a proposed draft treaty on ASAT weapons which provides that verification would be only by

national technical means of verification which we and the previous administration have concluded would be hopelessly inadequate.

Senator PELL. Obviously, that is clearly a proposed negotiating position. You go into it, you don't expect your offer that you make—if you are going to buy an automobile, a house, or an arms control treaty—that is going to be the final one. The important thing is to get into these negotiations and to get into them before, not after, these weapons are fully developed.

Mr. PERLE. It has to have a sound conceptual basis, and we do not know of any way that we could confirm compliance to our own satisfaction.

Senator PELL. Our only way to confirm it is to sit down and talk to them, which this administration seems determined not to do.

Finally, and this I guess would follow up with Dr. Keyworth, as I understand your system, your proposal, how would a human being in the loop—just explain to me where the human judgment would come in your loop.

Dr. KEYWORTH. First of all, I made a proposal and not a system. Let me be very clear on that.

Senator PELL. Very well. We understand. But where does the human being come in your loop?

Dr. KEYWORTH. First, let me speculate and say we will have a network of sensors and decision points where a human will, at the outset, have to decide exactly where each computer-based decision point will be made. That is a human decision in determining how the overall system is coupled.

Second—and I emphasize—it was pointed out earlier that the bolt out of the blue is not the most likely attack. I emphasize the importance of the so-called DEFCONS—defense conditions—that follow from increasing tensions. Those are, by themselves, individual decisions.

Senator PELL. We appreciate your answer. I think the record should show that you have answered very straightforwardly. The human gets into it before the attack occurs. But after the attack occurs, from your statement, as I understand it, there is no human judgment involved. It all depends on machines as to how well they are programed. And I think I am correct in that.

Dr. KEYWORTH. Yes, Senator, but I would also like to remind you how I responded to Senator Percy by pointing out that today we may well be required to accept a posture of launch under attack—20 to 30 minutes, even less—in which we would have to make that critical decision to launch nuclear weapons. We are not talking about launching nuclear weapons when we are talking about defensive technologies.

Senator PELL. My time has expired. Thank you.

Senator GLENN. Would you yield for one question?

Senator PELL. Yes, I would yield.

Senator GLENN. Is it the understanding, then, that once the system is in operation—and you are talking about the buildup to this—that once there would be an attack underway, that it would be completely automatic from there on, that the human would not enter the loop any time in that whole process?

Senator PELL. That is what he said.

Senator GLENN. At any step all the way through then, from the boost phase to the separation phase, over the hump phase, the whole works, right on down? That each one of a series of different things then would be completely automatic and dehumanized from there on?

Dr. KEYWORTH. Clearly, at any stage of the game, a human being can make a negating decision. What I am saying is that especially with the boost phase intercept emphasis, there is a matter of 2, 3, 4 minutes in which to take action.

That is a very short time for a human decision. A human decision can be made, of course, anyplace along the line. And what I am saying is that a negative human decision is the most likely option that would be pursued. But I must emphasize, we are not talking about taking a step that would injure a single human being.

Senator PRESSLER. Let me just say very briefly that since Mr. Perle mentioned my statements on MIRV's in both his opening statement and in one of his responses, I ask unanimous consent to put into the record excerpts from op-ed pieces that I wrote for the New York Times and for the Los Angeles Times on that subject.

[The articles referred to follow:]

[From the Los Angeles Times, Jan. 6, 1983]

AVOIDING A CRIPPLING SPACE-WEAPONS RACE

(By Larry Pressler)

In 1969, at the time that the United States entered the strategic arms limitation talks (SALT), the Air Force was about to flight-test a dramatically new weapons technology. This new concept, multiple independently targeted reentry vehicles (MIRV), represented a breakthrough in that each ballistic missile would have the capability to attack several targets. Concerned Senators asked that MIRVs be placed on the SALT agenda and that flight tests be canceled in the interim. The Nixon Administration rejected this advice in the belief that MIRVs would provide us with a significant military advantage that the Soviet would be hard pressed to match.

But the Soviets deployed MIRVs much sooner than expected, and now they are a principal cause of American strategic vulnerability.

Today, America is at a comparable juncture with regard to the development of space weapons, and the quest for short-term advantage may lead to similar long-term results. Unless there is a serious negotiating effort, anti-satellite (ASAT) weapons could prove to be the MIRVs of the 1980s.

In the early 1970s, the Soviets deployed an anti-satellite weapon that they have maintained and continued to test. Though this weapon has limited ability to attack large numbers of U.S. satellites, the absence of an American equivalent does make for a strategic imbalance. In the most recent test of this system in June, the ASAT was fired in coordination with launches of land-based and sea-based strategic weapons, a MIRVed SS-20 theater missile and antiballistic missile defenses. This demonstration led some analysts to conclude that the Kremlin views ASATs as an important element for waging nuclear war.

Should current trends in Soviet research continue, the threat to U.S. space interests will not come from ASATs alone. Moscow has an active laser- and particle-beam weapons-development effort that can be deployed in or directed at space. Though this program may not be completed for more than a decade, the Soviets are said to be at least five years ahead of us in the development of these death rays. Taken as a whole, the Soviets now spend three to five times as much as we do on militarizing space.

The United States must take defensive measures against these developments. To begin with, we can reduce risks by stocking backup systems that could be launched if our satellites are threatened. The space shuttle could help put replacement satellites rapidly into position.

Then, too, defense analysts may have wrongly weighed the current vulnerabilities of our space network by understating the weaknesses of our land-based satellite-control facilities. Given the small number of such locations in relation to the large number of satellites, it could be easier to neutralize our space network from the ground. The plan to add a space-control complex at Colorado Springs is a move in the right direction.

I have far less confidence in military countermeasures in space. Hardening satellites and/or providing them with the capability to maneuver away from an attacker would add significantly to satellite costs and reduce the payload directed at the satellites' primary mission—and it may not work. Countermeasures invite counter-countermeasures, and escape techniques are futile against beams traveling at the speed of light.

The most desirable remedy to the space-weapons threat is a ban on space weaponry. Arms-control talks aimed at this end have not received the attention that they deserve. The apparent successes on the ground of the yet-to-be flight-tested American ASAT are perhaps the chief cause of the neglect of arms control.

When our version of the ASAT was inaugurated, Washington's primary motive was to draw Moscow into talks aimed at dismantling the Soviet ASAT in exchange for cancellation of the American program. Three rounds of talks were held in 1978 and 1979, but were broken off after the Soviet invasion of Afghanistan, and the United States has made no effort to revive them. Strategic planners are reluctant to bargain away the American ASAT now that it appears that it will be significantly better than the Soviets' deployed weapon.

As in the case of MIRV development, the United States has sought short-run advantage. In the long run, the benefits will be meager. Given the current dynamics of the Soviet space-weapons development program, the failure to stop ASATs and other space weapons will surely produce new Soviet deployments. In this race, the United States has far more to lose because we will continue to depend on space systems more than the Soviets will. Oceans separate us from areas that are in our national interest to defend, whereas the Soviet Union is in the heart of Eurasia, meaning that, while land lines provide the Soviets with rapid communications to their military forces, the command and control of U.S. military units is best achieved via satellite. Also, the open nature of our society makes it much easier for the Soviets to monitor U.S. military programs without "overhead" reconnaissance than it is for us to monitor theirs.

Pursuing a space-weapons race makes little sense. We face major deficiencies in our existing force structure. Adding another dimension to the U.S.-Soviet competition would require spreading ourselves even thinner. Besides, avoiding war requires some degree of stability in military developments, and introducing a space-weapons race would undermine the delicate balance of terror as well as the predictability that defense officials require for effective force planning.

The United States has every reason to give space arms control a try. With our ability to quickly test and deploy U.S. ASAT as a backdrop, the Soviets may now negotiate seriously. Should negotiations fail, we would retain our current space-weapons option.

[From the New York Times, Jan. 13, 1983]

BAR WEAPONS IN SPACE

(By Larry Pressler)

WASHINGTON.—The current scare over the possibility that a Soviet nuclear-powered satellite may crash to the Earth's surface highlights the need for a space arms-control agreement. But despite the dangers posed by the space-weapons race, there are few indications that the Administration seeks to resume antisatellite-weapons talks. As the tempo of weapons development quickens, time is running out for reaching a comprehensive space accord.

In the first talks on the control of antisatellite weapons, in 1978 and 1979, the United States was eager for an agreement but the Soviet Union dragged its feet. No progress was made, and plans for continued talks were canceled in the wake of the invasion of Afghanistan. Today, Moscow seems eager to go back to the negotiating table—it has even presented a draft treaty to the United Nations—but the administration has shown no interest in resuming talks.

Moscow's eagerness—and our reluctance—are best explained by the state of space-weapons technology. The Soviet Union had a head start in developing antisat-

ellite weapons—its first was an SS-9 missile joined to a satellite interceptor. The Carter Administration followed with plans for an American "satellite killer" that it could use as a bargaining chip in negotiations with Moscow. But the Soviet Union was not impressed by an American antisatellite weapon that existed only on the drawing board, and did not dismantle its decade-old system.

We proceeded to develop our own antisatellite weapons, and the major American lead in micro-electronics and systems miniaturization has made for high confidence in Washington. Some analysts believe that our weapon, which joins an F-15 aircraft to a rocket and interceptor, would be able to knock out more than 100 Soviet satellites in a day. With the development of this weapon, we will effectively surpass the Soviet Union, capturing the military high ground in space.

But in their enthusiasm to win this space contest, officials have seemingly forgotten the primary goal of the antisatellite-weapons program—an inducement to arms control.

It is unlikely that the Soviet Union will stand still in its development of space weapons, and any advantage we obtain in space will be short-lived—particularly when the Soviet Union is willing to spend three to five times as much as we do on space weapons. Keeping pace in the competition will be expensive, and trying to add yet another dimension to the United States' already diverse and financially needy military forces may mean doing many things badly rather than a few things well.

Besides, we, far more than Moscow, are dependent on risk-free operation in space. The Soviet Union's central geographic position and huge land area provide it with land lines of communication to much of the globe, while timely control of American forces worldwide depends largely on satellites. Already the potential risk of a space-weapons race has encouraged some defense planners to look toward costly and diplomatically delicate land-based communications as a backup. In any case, many military operations such as the attempted rescue of hostages in Iran would be nearly impossible without satellites.

Weapons that effectively threatened our satellites would also compromise other important military space missions such as early warning of strategic attacks, verification of arms control agreements and reconnaissance. We can of course "harden" our satellites to resist attack, add to antijamming equipment and equip them to maneuver away from the energy's satellite killers. But this would greatly add to our defense bill and would interfere with our satellites' primary missions. The Pentagon has already requested that commercial satellites be hardened, perhaps making them uneconomical just when reduced cost has led to increased use.

This makes it all the more urgent to resume space-weapons negotiations. The United States should offer a nonrenewable two-year mutual freeze on flight tests of antisatellite weapons. If the Soviet Union resists this arrangement, we could begin with a ban on high-altitude antisatellite weapons tests. This would allow the United States to deploy its own antisatellite weapons in the short run and would protect many of our satellites. The restriction of antisatellite weapons testing is the first step—but the ultimate goal of negotiations should be a total ban on all weapons and hazardous objects in space.

Senator PRESSLER. Also, Mr. Perle and I had a debate on the "Today Show" and I suggested that the costs of some of these defenses would be from $100 to $500 billion to build. He suggested that I pulled those estimates from space. I want to put into the record a portion of the DOD 1982 study on laser weapons, as declassified and presented in previous Senate testimony, that suggested those estimates.

[The information referred to follows:]

SPACE-BASED LASERS—SUMMARY OF MISSIONS

Mission	Brightness W/SR	Schedule on-orbit/IOC	Weapon system cost (billions)
ASAT/DSAT	[Deleted]	[Deleted]	$50
Antiaircraft			50
Ballistic missile defense:			
Damage "denial"			500
Limited			100

Senator PRESSLER. Senator Tsongas.

Senator TSONGAS. The number of people who watch the Today Show, compared to the number of people who will read this record, will suggest that you lost that argument. [General laughter.]

It is called a second strike attack, I believe. [Laughter.]

If we could continue that, because the five-layered approach we discussed earlier—the first layer is the boost stage, and my understanding is we are talking up to 300 seconds. If you go to solid fuel propellants, you may, be down to 60 to 90 seconds; is that correct?

Whatr range of time are we talking about?

General ABRAHAMSON. Most of our ICBM's at this point in time last several hundred seconds, some up to 4 to 5 minutes during that initial burn phase. If we compare that to shuttle launch, for example, which has a very different trajectory than an ICBM launch—and any manned launch to low earth orbit would indeed have a different trajectory—that is 8 minutes and 20 seconds, I know, because I held my breath for all 8 minutes and 20 seconds, on the last 10 flights.

Senator TSONGAS. Well when the Soviets launch their first strike—and we all hold our breath—how many seconds are we talking about?

General ABRAHAMSON. We are talking about—well, let me ask Dr. Cooper.

Dr. COOPER. If I may address that question, what you are postulating is that the Soviets would build an entirely new, solid, rocket-propelled ICBM system that would burn out in 50 or 60 seconds. That is a tough problem. Current boosters, Soviet boosters, burn for 300 to 500 seconds, depending upon their targets and depending upon exactly where they are located in the Soviet Union. The post-boost vehicles burn anywhere from 60 seconds to several hundred seconds as well. So, for the first two phases of flight of the Soviet ICBM's today, with the current systems, you are talking about times on the order of 600 to 700 seconds.

Senator TSONGAS. So layer one would be geared toward that two-phase program?

General ABRAHAMSON. Yes, sir.

Dr. COOPER. Ten minutes.

Senator TSONGAS. Now, how many of the systems that we are worried about have that 10-minute booster stage?

General ABRAHAMSON. Actually, all of them. Some of them are slower than others. But all do, except for the very shortest range tactical nuclear ballistic missiles such as the SS-21.

Senator TSONGAS. Well, how much time are we talking about there?

General ABRAHAMSON. I would like to ask Mr. John Gardner, who can be more specific in this area, to respond.

Mr. GARDNER. In the process of looking at the amount of time available for the system to operate, of course, for the long-range ICBM's the times are long—10 or 12 minutes—for not just one layer of the defense system to operate, but most likely two layers would operate in that region. One layer to intercept during that booster burning phase, and another layer could be expected to operate during the time in which the vehicles were going through its

so-called MIRVing process in which another stage would be operating.

If you look at that same question for tactical missiles, you will find that some of the tactical missiles operate in a very analogous fashion. The longer range tactical missiles, for example, like the SS-20—the missile system that is so frightenting to our allies—operates in a very similar fashion, again taking 5 to 7 minutes to go through that process.

Senator TSONGAS. That would be the first two layers?

Mr. GARDNER. And the first two layers could be expected to operate during that time period.

Senator TSONGAS. As I understand it, layer one—you are talking about separate layers. How much time are we talking about within which layer one must be operative or is simply rendered ineffective?

Mr. GARDNER. Three to five minutes for current Soviet ICBM's.

Senator TSONGAS. OK. Who is the human being in that 3-to 5-minutes category who makes the decision? Clearly, it is not the President.

Dr. COOPER. No one knows what a future system design might be like. It could be possible that if tensions had risen and we were at DEFCON 4 or 5, that the President would be available and could make decisions on a few-minute time scale. But no one knows the answer to your question. No one knows exactly what the system design would be or what technology it would employ to put the command and control authorities into a position where they could start and stop the system.

Let me point out, Senator Tsongas, that this is no different from the system that was designed in the late 1960's and was fielded as the Safeguard system. The Safeguard system had the potential only to be started or stopped. There was a period of time in which a decision could be made to start it, and then at any subsequent time, the system actions could be stopped. But the actions of the system itself were completely automatic, completely under the control of computers of a 1960's vintage.

What we are talking about are technologies of the 1990's, to the year 2000, technologies that will be 30 years in advance of the technologies you are talking about. In many of those cases, you will find that the computer technology will allow much of the process that normally goes on in human ways to be done by machines, but still reserve the essential decisions for the command authorities who are able to take decisions at each step along the way.

The answer to your question strictly is, no one knows what the design of that system would be like or how we would take into account the serious problem which you bring up of keeping the national command authorities completely in control of the strategic situation.

Senator TSONGAS. Well, that would argue that in the 1990's we should run R2D2 for President, because he would be on line all the time. [Laughter.]

I mean, I am asking a serious question. What you are saying basically is that if there was a launch without tension, the likelihood, the certainty, is that the President of the United States will have absolutely nothing to do with layer one decisionmaking.

Dr. COOPER. Not true.

General ABRAHAMSON. Sir, I would like to put a comment in. First of all, we all understand that we have a challenge here, to try to come up with a system that human beings can appropriately be part of. I think there is an important perspective brought up by Dr. Cooper's comment that the Safeguard system of the 1960's in fact operated in that same way.

Right now, today, the Soviet system must be operated in exactly the same way. They cannot have an effective way in which human beings can enter into their decision process any differently than we do. In fact, it must be less effective because our computers are much more advanced than theirs.

Furthermore, the President of the United States has only between 6 and 10 minutes today to make a decision about a submarine-launched ballistic missile [SLBM] standing off our coast. In that case, we are not talking about a defensive system that knocks down and eliminates a ballistic missile, but we are talking about this terrible decision that the President must be faced with. Do I or do I not activate a retaliatory strike?

Senator TSONGAS. Has the President been informed that he is out of the decision-making loop?

General ABRAHAMSON. Sir, we have not defined this whole program yet. I think that is a key and important point.

Senator TSONGAS. Have you said to him, "Mr. President, the likelihood is, if there is not tension so that we know it is coming—sort of like covert activity in Nicaragua—that if there were a strike, the fact is you are not in the decision-making process." Have you said that to him?

Dr. KEYWORTH. I certainly have not. [Laughter.]

Senator, I think we are obscuring the central point. This is not an analogy with initiating a war or carrying out a war. It may very well be nothing more than sending a few beams of light out into space. No one is to be injured.

Senator TSONGAS. Who has told the President, if you haven't, and you are his chief scientific advisor, who has told the President that the likelihood is he will not be in a decisionmaking position if we launch the "Star Wars" system? Who has told that?

Dr. KEYWORTH. Senator, the President is perfectly clear of the exact time sequence that you have asked. We have made that clear to him. He understands it perfectly. You are asking for a decision that is not an analog to the nuclear launch decision. It is a totally different situation.

Senator TSONGAS. So you have told him that he is not the decisionmaker in this process.

Dr. KEYWORTH. I most certainly have not.

Senator TSONGAS. Well, how could he infer that?

Dr. KEYWORTH. The President knows this is a layered defense. It has multiple layers. The first layer has a maximum of 5 minutes, the next has a maximum of 20 minutes, and the third one is a very short period of time. Each layer requires certain decisions.

Mr. PERLE. May I add something?

Senator TSONGAS. Have you told him, Mr. Perle? Are you the one who had the duty of telling him he is not part of the process?

Mr. PERLE. Senator, I have to say that I do not understand your concern, and I would like to understand your concern. You are hypothesizing a situation in which a nuclear attack is launched on the United States, in which hundreds or perhaps thousands of nuclear warheads are headed for the destruction of our homeland, and you are worried about whether the President is going to make a decision to intercept those incoming warheads.

Frankly, I think the question of Presidential intervention or any other intervention is a minor, second-order issue when the real issue is whether you do or do not stop the destruction of the United States.

Senator TSONGAS. How does the President feel about your viewing him as a minor, second-order level of decisionmaking?

Mr. PERLE. I said the decision is a minor decision because it does no harm if it turns out there is not an attack, and if there is an attack——

Senator TSONGAS. Mr. Perle, some of us believe that a nuclear war is not a minor decision. And to describe that as a minor decision suggests why there is such a gulf between those of you at that table and some of us up here.

Mr. PERLE. I think you have distorted the clear intent of what I have said.

Senator BIDEN. If the Senator would yield, the point that Mr. Perle is making, I am a little confused about. I think I understand what he is saying, but I wonder if, in fact, this defense system is activated to shoot down those incoming missiles that are threatening our homeland, aren't they the same things that could be activated to shoot down a Soviet space system?

Mr. PERLE. As General Abrahamson has observed, there are very different trajectories for the two types of launch. It is a system that would discriminate among trajectories, and there are many other ways in which that sort of judgment could be made.

Senator BIDEN. Let's assume that we miscalculated about the scope, the size, the launch on the Soviet end, and we activated without the President being a part of the loop, which is understandable to some degree, according to what you have said. We activate the first layer. Are the Soviets sophisticated enough and are you sure enough that they will conclude, since we made a mistake, that it was a mistake and not an attack upon their space-based systems, causing them in turn to assume that we have begun the first stage of a nuclear war?

Mr. PERLE. We are not talking about a system attacking space-based systems, but rather in the first layer, Senator, ballistic missiles that have been launched and that are in the burn phase. There is no possibility of that sort of confusion.

Senator BIDEN. Are you saying there is no possibility on the part of the Soviets that the launch that takes place in our first stage—that that launch is one that could only be read by the Soviets as being a launch——

Mr. PERLE. But it is not a launch; it is the activation of a weapon, that, if it did not strike a Soviet ICBM on its way to the United States, would have no other effect.

Senator TSONGAS. Would the Senator yield? That is not true, because we are also talking about pop-up systems, and you have to launch a pop-up. Is that not correct?

Dr. COOPER. Senator Tsongas, that is exactly why I said before that no one knows the architecture of any future ballistic missile defense system that may come out of this research program. It is completely unknown.

All of these issues which you are bringing up, which I think are spurious issues at this stage of the game, are issues that will be addressed by the research program, and all of those issues will have to be suitably accounted for and taken care of in our research program, or no system will be possible.

Senator BIDEN. I am not so sure they are spurious. I understand your feeling about spurious, and I thank you for letting me interrupt, Paul, but I would like to go back to the point that if, in fact, Doctor, you and the Secretary are correct, that there is absolutely no way in which a reasonable person, sitting on the Soviet side of the equation, seeing the system activated in layer one would read that activation as anything other than a misunderstanding that we were under attack, that we thought we were under attack and we may have been mistaken.

If there is no reasonable case where a Soviet planner, sitting on the other side detecting—I assume they could detect the activation—that they would say, well, they just were mistaken; there is nothing to worry about. Is that it?

Mr. PERLE. What do you think they might conclude?

Senator BIDEN. What do I think?

Mr. PERLE. Yes.

Senator BIDEN. Well, the point is I do not know. You are the experts. My guess is that if, in fact, the same system, but for the trajectory, could be the vehicle by which we would in fact eliminate any space-based system they have, those dirty old Soviets might think that we were beginning the first stage of a means by which—you, by the way, Mr. Secretary, in your anti-SALT days, made the argument that when in fact the reason why we would be able to have an attack and the Soviets could strike us first and all of that, was that they would knock out our space-based systems first, and then the following scenario would occur.

Now, I am just wondering, and I do not know the answer. I am just asking. I am sincere when I ask, is it reasonable for the Soviets to conclude, if in fact we mistakenly initiated the system, would there be, you know, no harm, no foul?

Mr. PERLE. The Soviets would know that their satellites have not come under attack. They would know that.

Senate BIDEN. But you do not think they would conclude anything else? You think they would conclude that it is a mistake? You do not think they would think that they in fact were under attack and we just blew it, that we missed it, which means they better do something?

I mean I am so used to hearing you make those arguments about how, in fact, we have to understand the Soviet mind and how the Soviets are, in fact, so paranoid and so defensive that they, in fact, have to conclude—it is like the second-guess thing—that they think that we think that they think—I heard you make those kinds of

cases on other matters with regard to Soviet activities, and I am wondering whether or not it might not be appropriate here.

And if it is not, I accept that. But I am serious. It is a serious question.

Dr. COOPER. Senator, it is not clear that you are not bringing up a situation which could never occur. And that is why—I guess I do not fully understand precisely what situation you are bringing up. Are you saying that this proposed, unknown, unspecified system of the future, which nobody knows the nature of at this stage of the game, might attack an orbiting spacecraft accidentally, or it might attack accidentally a space launch from the Soviet Union in the boost phase?

Which one of those things are you talking about?

Senator BIDEN. Well, I guess you were not listening to the debate that was going on between the two men at the end of the table and my colleagues here, which concerned whether or not the human factor not being in the loop was something we should worry about or was OK.

Dr. COOPER. I understand that, sir.

Senator BIDEN. Now, let's assume that you are all correct—and I believe you are—that in a nontension filled situation, where we have not gradually moved to DEFCON 1, that there is a judgment made by someone—and we acknowledge that we do not know who that is—that we are under attack, just the bolt out of the blue, and, in fact, the next step is the automatic initiation within 2, 3, 4, or 5 minutes, of the first level of this defense system, and this takes place. There is no knowledge of the human factor, we don't know the human factor.

Dr. COOPER. Exactly, we don't know.

Senator BIDEN. But it is more likely in that timeframe. It is not likely to be the President, it is not likely——

Dr. COOPER. Why not?

Senator BIDEN. Well, unless he happens to be sitting there at that moment.

Dr. COOPER. No, not necessarily. It is quite possible that the technology could go right along with him, even into the bathroom.

Senator BIDEN. OK, fine. [General laughter.]

So, the President is having a shower and he hears a beep.

Dr. COOPER. That's right.

Senator BIDEN. All right, whatever. I really do not want to turn this into a carnival. I am trying to ask a serious question.

Let's assume the technology goes along.

Dr. COOPER. Well, it sounds a great deal like that, because you are creating artificial phantoms that you want to shoot down. What we are saying is that your artificial phantom is of no consequence. No one knows what that future will be like.

All we know are what technologies we will work on to try to prepare or to create options for the future.

Senator BIDEN. Wonderful.

Now, the President makes the judgment, sitting in the shower, that, in fact, he has to make within the next 90 seconds a decision to, in fact, initiate phase 1, level 1, of the defense system. He makes that. And you have developed the technological capability

where he can not only receive the information, but he can digest it and he can decide, and he can make that decision known.

Dr. COOPER. And he can consult with his advisers. He can do all of the things that he does today.

Senator BIDEN. He can consult, fine, wonderful.

Dr. COOPER. He can do all of the things that he does today, and he can do that in a short period of time. There is no reason to not postulate that we can achieve that technology.

Senator BIDEN. That's reasonable, you are right.

Senator TSONGAS. The adviser is in the next shower.

Dr. COOPER. Absolutely—or in a shower in the next State, or wherever.

Senator BIDEN. All right, it is all possible. That's fine and I am willing to agree with that.

Now, phase 1, after consultation, a decision is made by the President to initiate phase 1, level 1.

Now, let's assume that it was a mistaken judgment.

Dr. COOPER. We are not ready to assume that, because we don't know but what in that time period we couldn't create technologies that would not make such a mistake possible.

Senator BIDEN. You have convinced me that I don't want the program in the hands of a man like you.

Senator PRESSLER. At this point, we will turn to Senator Glenn. But first we must attend to one item of business.

We can do this quickly.

[Whereupon, at 11:59 a.m., the committee recessed, to reconvene immediately in a business meeting.]

[Whereupon at 12:03 p.m., the committee resumed its hearing on strategic defense and antisatellite weapons.]

Senator PRESSLER. Senator Glenn.

Senator GLENN. Thank you, Mr. Chairman. I have a very basic question.

We talked about layers 1 through 5, and whether the President is in the shower or not and who has been handing him towels before he makes this important decision and all that sort of thing. It obviously gets a little ludicrous.

A very basic point that Dr. Keyworth made starting out was that we were not going to discuss specific technologies; not now. And yet, the whole thing rests on that.

I have followed all the different types of lasers, high velocity kinetic weapons, particle beams, and such for I guess about 15 or 18 years now, and my big objection to this whole thing is it has not yet been invented.

I have supported laser research and particle beam research for ground use and for battlefield use and so on in the thought that perhaps it might have some application in the future, perhaps in space, too. But it seemed to me, and it seemed to me ever since the President has talked about this that what we are talking about is something that has not yet been invented. While I support research, all this business of going on with proposals for deployment and such are so premature at this point that I cannot believe we are discussing layers 1 through 5 and are just assuming that the basic physics of this thing works. That is a long way from being proven.

It may be another 15 or 20 years before we have the thing workable.

I just can't see this. The President far oversold this. I thought it started for political reaons. If he wants to appear to be Buck Rogers out there, defending the country, that is fine. I appreciate that. But I just cannot see us going through all this business of deployment, having great teams going out, doing decisionmaking and all of that business when the basic system has not even been invented.

It is so preposterous to me that it has been carried to this extent by the White House that they would talk about it at this level, as though we were about to deploy. We are arguing about things that I think are just semantics at this point until the whole thing gets invented.

General, I disagreed with one of the things you said earlier about this being very similar to John Kennedy saying we will go to the Moon. It is not. I will disagree with you on that.

That was an engineering problem. It was not a scientific breakthrough problem. We did not have to invent rockets at that point. We did not have to invent rocket fuel. We did not have to put new engines together. We knew the physics of the whole thing. All it involved was doing the hard, tough, grinding engineering work with slide rules and computers, back in those days, to put the whole thing together. It was a matter of whether we were going to go Earth orbit or lunar rendezvous and some questions like what was most energy efficient. But the engineering work was all that had to be done.

Here we have to make some very basic breakthroughs, it seems to me, in lasers, in particle beam research and things like that. I have supported that kind of basic research for earthbound uses, whether or not they ever have any application in space. I think that is still academic.

I think the whole idea of going ahead and spending a lot of money is foolish. Secretary DeLauer said to me that maybe his estimates are that it could be as much as eight times the Apollo program in expense and could cost up to a trillion dollars. Why go ahead planning now to deploy this thing before the whole thing has ever been invented?

I would welcome anybody's comment on this.

I think you have the cart way out ahead of the horse. We are planning deployment. We are talking about different layers, about different applications of things that have not even been proven on the ground yet.

Dr. COOPER. Senator, you are exactly right, and I agree with you 100 percent—that is, we are talking about technology which is not mature. All this program has been represented as, both by the President and from the Defense Department, is as a research and development program to bring the technology which might be applied in this area to maturity.

We have estimated 10 to 20 years to do that.

I agree with you that it is not an engineering problem. There are some basic and fundamental things that we need to develop, particularly in the data processing area.

Senator GLENN. The way the President has presented this and the way it is being talked about around the country, I can tell you from personal experience, having been around much of this country during the last year and a half, that the people of this country think this is ready for deployment. They think it is ready to go.

Dr. COOPER. Clearly, we should all work together, then, to disabuse them of that because it is a research program and it clearly is aimed at systems of the distant future.

Senator GLENN. Way distant.

Dr. Keyworth, you have followed this thing for a long time. What is your estimate of when this technology may be available to really even consider any of the things we are talking about or even consider it for battlefield use.

Dr. KEYWORTH. Most certainly, it is some time. Senator Glenn, I agree with virtually every word you have said. You have just described, I think, one of the problems that has precluded much rational discussion of this subject.

If you go back and look at the President's speech—and I would be quite happy to send you a copy—you will find that it was entirely research oriented, tentative, searching for new options, and in the future.

The problem, I am afraid, is that the very same desire that drives so many of us to place great emphasis on arms control, has created, let us say, a premature enthusiasm. We are not there yet. We are most certainly nowhere near making a deployment decision.

Senator GLENN. I think there are some things in the President's speech that go well beyond what you have just stated.

I don't have time to go through the speech. I have a copy of the main parts of it here with me, though. He went well beyond what you have just said—calling it just a research program trying to develop this technology.

Dr. KEYWORTH. I think the accounts of the President's speech did.

Senator GLENN. I have here a Washington Post article of March 24 of this year. The Secretary of Defense is quoted as saying, "What we want to try to get is a system that will develop a defense that is throughly reliable and total. I don't see any reason why it can't be done."

Well, I do. It hasn't been invented yet. [General laughter.]

Maybe the Secretary of Defense knows something that I am not aware of. I have had every blooming briefing on this subject that I think anybody can possibly have. I think I probably have kept up with the technology of it as closely as any U.S. Senator because of my background and interest in it. It is just not here yet.

The President has misled the people of this country into thinking it is here and now.

I diagree with that.

Mr. PERLE. Senator, the Secretary of Defense is describing an objective.

General ABRAHAMSON. Yes, I think that is the key.

Mr. PERLE. There is no reason to think this is anything other than an objective. Indeed, much of the rhetoric that creates an impression that some deployment is imminent is coming from critics

of the program. I picked up the Washington Post this morning and read about former Vice President Mondale from Wintom. I will quote: "President Reagan wants our country to spend hundreds of billions of dollars developing 'Star Wars' missile systems, and at the same time he doesn't want our country to push for the treaty on antisatellite weapons."

This administration has made no decision to spend hundreds of billions of dollars. What we have is a technology development program, a research program. This is clearly spelled out in all of the budget submissions and the testimony is in support of that.

We regret as much as you do the impression that there is imminent deployment because there is not. It is a long-term effort.

Senator GLENN. Do you agree that there is that impression in the country?

Mr. PERLE. I agree that there is that impression. I think it results in large measure from the exaggerated criticism of the program in which figures like a trillion dollars are routinely thrown around. When you talk about trillion dollar programs, you obviously must be talking about deployment.

Senator GLENN. That is Under Secretary DeLauer's statement, I believe, not mine.

Dr. COOPER. Senator Glenn, may I just speak for Dick since he is not here, because I do know his views on this.

What he said precisely was that it is not inconceivable that, should a deployment decision be taken in the future, it could cost a fraction of the defense budget which was not dissimilar from the fraction that we now spend on strategic offensive forces.

Do you know how much we have spent on strategic offensive forces since the 1950's?

Senator GLENN. No.

Mr. COOPER. It would certainly make a trillion dollars in today's dollars pale in significance.

It is not inconceivable that the costs could be of the same order, in his view, as that which we spend on our strategic forces.

Senator GLENN. I believe, too, it is Under Secretary DeLauer's view that the SDI will examine only about half the strategic defense problems and that dealing with the air-breathing threat requires another major defense initiative like that.

We are talking sums that are unbelievable.

Dr. COOPER. Sir, it is true that we are studying the air-breathing threat. That study was ongoing well before the President made his speech last year, and there have been proposals, some of which have been funded in the fiscal year 1985 budget, to begin to work on the problem of defense against the air-breathing threat as well.

So, the air-breathing threat is clearly something in which we have an interest and which we will be attacking over the next few years in our R&D programs.

Senator GLENN. I would make one other comment about the ASAT and verifiability.

It would seem to me, Mr. Perle, that the administration has very selective verifiability objectives—I guess that is what I would call them. I see absolutely no reason why we do not negotiate with the Soviets on this. We have talked about the lack of verifiability. I

have been one of the leading people here worrying about the verifiability of various arms agreements.

You may recall SALT II and the arguments we went through in those days. I took a lot of flack for my position on that. And we can verify SALT II now, so I think that should be sent up again. It is a different ballgame now than it was several years ago.

But why would we call for a ban on chemical weapons and be willing to negotiate chemical weapons, which are far more difficult to verify than anything to do with ASAT's? ASAT's are out there and you have to shoot them. You have to test, you have to do all sorts of different things, put missiles on pads and so on. But it is far more difficult to verify chemical weapons. Any yet we say we are going to go ahead and do that.

We are willing to negotiate something that is more difficult to verify, and yet we turned down ASAT, but are willing to go ahead with chemical weapons, which, it seems to me, has so many more verification problems than ASAT.

Mr. PERLE. Senator, I disagree about the difficulties of verification.

There are a variety of means, about a dozen or so, by which the Soviets could hope to attack and either destroy or destroy the effectiveness of our satellites. Many of these involve technologies that have other applications, and verification includes more than the observance of activity. It involves the ability to reach a judgment that that activity is prohibited because it constitutes a violation of an agreement.

We figure that with some potential ASAT systems we would have an all but impossible time establishing that the activity we observed was, in fact, ASAT-related activity.

But beyond that, and of greater importance, we have proposed, as you know, in the effort to ban chemical weapons, an inspection regime which would permit an international team of inspectors to go anywhere at any time.

Senator GLENN. Is it our view that we are going to do the same thing with ASAT's?

Mr. PERLE. The difficulty there is that a small violation of an ASAT ban would have immense military consequences. What we are talking about, for example, in the case of the existing co-orbital system, is the hiding of a relatively small number of chemical weapons. It would not be of such decisive consequences.

The situations are really not comparable.

Senator GLENN. Well, let me say one thing.

I think, when we go into these negotiations, one of the items is verification. You don't say we can't verify before you go in. Maybe the Soviets have some idea on Soviet verification or are willing to give some, or are willing to make onsite inspections, willing to tailor their production of whatever it is to certain points so that we could monitor them—why who knows what you would get into?

I see nothing being lost by going into negotiations on this because verification becomes one of the items for negotiation, whether it is onsite or whatever. You would have to do that for chemical weapons, so I don't see why it would be impossible to do the same thing with ASAT.

Mr. PERLE. We come to the conclusion that with the sort of onsite inspection that we would propose in support of a chemical weapons ban, we would have reasonable confidence, given the consequences of a violation; and, we have similarly concluded with respect to a comprehensive ban on antisatellite weapons, that we could not have reasonable confidence, even with a very high degree of Soviet cooperation.

It is a judgment call, and I believe this administration has pushed firmly, both intellectually and in its proposals, the concept of onsite inspection and cooperative means of verification, and we are proud of that record. But we genuinely believe that there is one instance where we cannot have sufficient confidence. I must say that that judgment has been influenced, and I believe properly, by the fact that the Soviets are presently violating the SALT II Treaty, the ABM Treaty, and other international obligations. Where you have such freedom under the terms of those treaties—you almost have to go out of your way to violate them—the returns are marginal to the Soviets as a consequence of cheating. With respect to an ASAT ban the returns would not be marginal; they would be profound.

Senator GLENN. I think anytime the Soviets are in a negotiating posture, we should go ahead and negotiate and make the first item of negotiation how we are going to verify whatever we are going to agree to. Make that the first item for negotiation.

Mr. PERLE. We have been discussing that.

Senator GLENN. What are you looking at, what are you doing?

Mr. PERLE. We have been discussing verification, or attempting to discuss verification, with the Soviet Union, in Geneva, at the Conference on Disarmament. Their attitude has been discouraging.

Senator GLENN. Well, start them up again.

Senator PRESSLER. I think what we will do is plan to break at 1 o'clock and come back at 2 o'clock.

I have a few more questions and I believe Senator Tsongas has a few more for this panel.

There is one thing I particularly want to say.

Let me say to you, Secretary Perle, that I very much admire you. You permeate the entire arms control area and though we disagree on a lot of things, I very much admire the way you control the area. As the chairman of our Arms Control Subcommittee, that has been my observation. I say that in an admiring way, though we come to opposite conclusions.

We had hoped today—and I am sure you were involved in the decision—and we did request that Dr. Richard DeLauer would testify. He is still the Pentagon's Research Chief.

Did his criticism of the Strategic Defense Initiative lead to his withdrawal from today's hearing?

Mr. PERLE. There are people who work for Dick DeLauer here now, and the answer is absolutely not.

Senator PRESSLER. May we hear from him at a later time?

Mr. PERLE. I think that is a matter between you and Dick DeLauer. I have never known Dick DeLauer to shy away from speaking his mind.

Senator PRESSLER. We did invite him and would very much like to hear him. Perhaps if we are going to be resuming this afternoon,

we can hear from him. I am sure with a phone call you could get him here.

Mr. PERLE. I, frankly, do not even know whether Dick is in the country.

General ABRAHAMSON. Or whether he is in Washington.

Senator PRESSLER. Would you check on that, please? Could we hear from him in the future if not today? We would like to hear from him today, if possible.

Senator TSONGAS. Maybe we could call him to see if he is in the country.

Senator PRESSLER. We will be in session this afternoon and would very much like to hear from him, if possible.

Senator TSONGAS. If there is at least a 50/50 chance, we should at least try. Maybe even 85 percent? [General laughter.]

Senator PRESSLER. I have a final question.

Dr. Cooper, in recent testimony before the Armed Services Committee, you expressed reservations about the feasibility of protecting the U.S. population from a nuclear attack.

Would you elaborate on that? If populations cannot be protected, do you believe defending missile silos is worth several hundred billion or perhaps even a trillion dollars?

Dr. COOPER. Senator, I think the testimony that you are referring to is the colloquy between Senator Nunn and ourselves in the Strategic and Theater Force Subcommittee of the Senate Armed Services Committee.

In that discussion, the question came up as to when we would be able to reduce the size of the U.S. strategic nuclear force as these strategic defense technologies came on.

I believe all the witnesses there at the time said that it was not possible to say whether in the future we would be able to create completely effective, that is, 100 percent effective, defenses. But that was our goal; and, until we could, our strategic offensive forces would have to be maintained at some level.

I still believe that is the case. I think it is a reasonable goal to try to get a perfect defense, but that it is going to be a very difficult goal to achieve. I am certainly glad that we have Jim Abrahamson working on that problem now, because he is probably one of the best qualified men in the world to work on it.

Senator PRESSLER. If we can get Dr. De Lauer here this afternoon, I would very much appreciate it. If not, we would like to get him over here at another time to get his views.

Do you have another round of questions, Senator Tsongas?

Senator TSONGAS. I would like to address the question of impressions.

As Senator Glenn quoted the Secretary of Defense, "I don't see any reason why it can't be done," that is, a thoroughly reliable and total system, would that not give the impression that at least he thinks it can be done?

General ABRAHAMSON. I would like to comment on that, if I might, sir.

There is a difference between thinking that something can be done and believing that there is a chance in terms of going forward and a commitment to make a deployment decision.

I see Senator Glenn has left, but since I did make that parallel and frankly there is no one in this room who can dispute his view, I would like to amplify what I was trying to say.

I believe that what President Kennedy did is he committed to an extremely difficult challenge. When he made that kind of commitment, it was a commitment to not only a goal, but one to accomplishing that goal.

Now, there may well be the differences that Senator Glenn pointed out, that there are some basic science efforts, milestones that must be achieved before we can proceed. And in this case, the difference is the President has laid out a long-term goal for us, but only committed at this point to the first step.

The first step is the research and development to prove that we can make the second step.

Many of us believe that we can do that.

Senator TSONGAS. Well, where is the statement that says "I am only committed to the first step?" I have the speech.

General ABRAHAMSON. I think that what the Defense Department has presented with many witnesses over time here is that we have only proposed a research and development program.

Senator TSONGAS. You just said that the President has said that he is committed to the first stage. Where, exactly, in his speech is that reference?

Dr. KEYWORTH. Senator Tsongas, if I may comment, and I don't have the speech——

Senator TSONGAS. "There will be risks. Results take time, but I believe we can do it."

Does he mean stage one?

Dr. KEYWORTH. No. The President means that he can achieve the objectives that he stated at the early point of the speech.

If we are discussing Secretary Weinberger's use of the word "total" and folding it into the context of the President's speech—I would like to get the question clarified.

Senator TSONGAS. You just said that the President is only committed to the first stage, which is research and development. I am asking you where in his speech does he say that?

General ABRAHAMSON. Senator, I think that you are twisting both what my intent is and what I believe we all have just said and what I just said as well.

Senator TSONGAS. Could the reporter read back—do you have that available.

General ABRAHAMSON. Let me tell you one more time what I think it is that I was trying to get across so that there is not any question.

What I said was that the President said he believed we can do it. Mr. Weinberger has said that, and, frankly, I do as well, as do many other scientists, engineers and people who have studied this overall program.

However, the commitment in terms of what should we do as a first step is exactly what the Department of Defense has proposed, and that is a research and technology program to answer a series of questions.

Now, those questions are both technical and policy questions. There has already been very fine initial work done in both of these.

The Fletcher Committee is a fine example of the work done which validates the fact that many people do believe it can be done.

An architecture was laid out there, but only an architecture, and not a specific system. I think that is extremely important.

Senator TSONGAS. But the President believes that it can be done?

General ABRAHAMSON. That's right.

Senator TSONGAS. Now let me ask you to define "it." He believes it can be done. Is "it" a total and thoroughly reliable system?

General ABRAHAMSON. In terms of what he said, "I am directing a comprehensive and intensive effort to define a long-term research and development program to begin to achieve our ultimate goal"—and this is the "it"—"of eliminating the threat posed by strategic nuclear missiles."

Senator TSONGAS. So, when he says that he has faith and "I believe we can do it," he means I believe we can launch the research and development phase?

General ABRAHAMSON. Well, no. Let me tell you what I believe.

I have not had this particular talk with the President, but I believe that this nation has the technical muscle so that if it indeed is in our final policy interest, and that is something that has to be judged at each step along the way, that we can build such a system. I have a lot of basis for that based in terms of other programs, such as the Apollo program, and such as the shuttle program, that I have been a part of.

Frankly, I think most Americans agree that when we set out on one of these technical programs and set out with a national resolve to find an answer, that we can do these things.

Now, there are a series of concerns that people have stated.

You just stated a very specific concern, narrowed down to just one of the small parts of the system.

I would not dismiss that, and I do not. Those are such as the one that we were discussing earlier—how and when does a human being involve himself properly in the process? Also, at what level should the President be involved? How do we avoid a mistake? Those are all important parts of the research effort.

All I can say is that I understand those concerns. I understand the concerns, some stated by critics and some stated in a very constructive way.

That, indeed, is part of our intent—to go ahead and find appropriate ways to solve those problems.

Now, the bottom line, however, is that I believe we can do it.

Senator TSONGAS. As I recall there was a very strong support in the Congress and in the country for both the Apollo program and the space shuttle program. In fact, I don't recall there being any serious segments against it. I don't think that will be the case here.

Let me ask Dr. Keyworth this. Can you describe how this issue was raised to the President, who did it, and under what circumstances?

Dr. KEYWORTH. Senator, I can certainly relate to you my own awareness, but I am also convinced that it emerged in the President's mind spontaneously.

It came following a very difficult period——

Senator TSONGAS. I didn't hear that. There was a noise over here. What was your last sentence?

Dr. KEYWORTH. It was the President's idea, and it came following the year that you will well remember as being the year of the strategic modernization decision, a sequence of very difficult decisions.

The President discussed with me and many others the feasibility, of the concept and the opportunities, the question of stability, the question of our allies, and many, many other issues. It was very carefully thought out. But it was not something that was sold to the President.

In fact, I have not seen very many things sold to the President.

Senator TSONGAS. So, he was the one who first raised the issue of the "Star Wars" system?

Dr. KEYWORTH. The President is by no means the first person who has raised the strategic defense. The question of raising it to public attention as a major strategic goal, the first step of which would be a research program, was the President's own initiative.

Senator TSONGAS. Wait a minute. When you said it was his idea, are you referring to phase I was his idea or the concept was his idea?

Dr. KEYWORTH. Senator Tsongas, you have gotten us so confused with phase I being a research program or phase I being boost phase intercept that I think this is intangled in almost incomprehensible logic.

Senator TSONGAS. Well, I would agree with that.

Dr. KEYWORTH. The President's objective is clear. The source we might disagree upon.

Senator TSONGAS. Can you describe for us the first circumstance in which you and the President talked about this system?

Mr. KEYWORTH. During the course of the time that I have been the President's science advisor, the issue has come up on numerous occasions. The President has certainly discussed strategic defense with others, prior to being President.

The "it" on which I will focus is the speech that he gave on March 23 and the decisions that preceded that. All I am relating is that it was the President's decision to give that speech and its contents and its timing.

Senator TSONGAS. I do not disagree with that, but whose idea was it originally that there was such a thing as this "Star Wars" or SDI? Who was the first to raise it? Did he raise it with somebody, or did somebody raise it with him?

Dr. KEYWORTH. I do not know. It certainly must be before the Second World War that earliest dreams of this ever came out. I have no idea, but perhaps if you would explain to me the point of the question, Senator Tsongas, I would do my best to try to clarify it for you.

Senator TSONGAS. Well, I am trying to figure out how this thing came about. There have been various press reports about people going into the office to speak to the question, and when I raised that, you said that this was his idea. And I am trying to figure out, what was his idea?

Dr. KEYWORTH. It is my understanding that the President has been interested in the subject of defense for some considerable period of time preceding his election to the Presidency. As far as the detailed discussions that have occurred, the individuals in-

volved, and the timing, I do not know, and if I did, I doubt if I would be at liberty to discuss them all——

Senator TSONGAS. Then how do you know it was his idea?

Dr. KEYWORTH. Well, the "it" I will define again, for the third time. The "it," the speech on March 23, his decision to give that speech with that content at that time is the "it" to which I referred. That was his idea.

Senator TSONGAS. OK. The speech was his idea. You said no one sold this to the President.

Dr. KEYWORTH. That is correct.

Senator TSONGAS. But that presumes that it was then his idea, that no one went to him with this idea.

Dr. KEYWORTH. Let's go to the other extreme, Senator. Are you asking me, did the President invent the strategic defense concept?

Senator TSONGAS. Am I suggesting that?

Dr. KEYWORTH. Yes.

Senator TSONGAS. I would not even dream of suggesting that he has devised this system.

Dr. KEYWORTH. Are you implying, is there a single person who walked in and convinced the President that this is an important approach to this country's national security?

Senator TSONGAS. I have not been in the oval office in 3 years and 4 months. I have no idea what is going on in there. I am simply asking you, as the chief science advisor, how this thing came about. And you are telling me he thought about it before World War II. I was not even born. How can I refute your comments?

Dr. KEYWORTH. First, I did not say that the President thought about it before World War II. I said the concept of defense against airborne objects precedes World War II, not the President's interest in this. I cannot testify as to when the President thought about this, and I am not even sure it is an appropriate discussion or question.

Senator TSONGAS. OK. But you cannot say that the concept was his idea. The speech was his idea, but the concept was not.

Dr. KEYWORTH. I will make two points again. The President did not invent the concept of ballistic missile defense.

Senator TSONGAS. OK. That is the only point I wanted——

Dr. KEYWORTH. Second, the giving of the speech, its content and its timing, was the President's own initiative and objective.

Senator TSONGAS. Fine. That is exactly what I was trying to get you to say.

Now, can we talk about the 85-percent figure? The mathematics I have done show, if you take 10,000 warheads through 5 layers and each one of them is 85 percent effective, 1 warhead survives, so that gives you a system that is 99.99 percent effective.

How did you happen to pick, in open public testimony, 85 percent as an illustration? We talked about expectations. The only figure that has been referred to was one that was 99.99 percent effective. If it were 50 percent effective, my calculation is 312 warheads would survive. How did you pick 85 as opposed to 50, for example?

General ABRAHAMSON. Because it was a precalculated number; that, in fact, I was aware of the total kinds of numbers, and it is in some of the reporting as something that is attainable.

Senator TSONGAS. But we have not even discussed the physics of it. How do we arrive at 85 percent? That is a very specific number.

General ABRAHAMSON. I would like to ask John to help me with this. We would have to go into the Fletcher report at this point in time.

Mr. GARDNER. Last summer, of course, Dr. Fletcher and the group of people, of which I was a member of the group, spent a good amount of time trying to attempt to understand what the technical potential was. In the process of doing that, a number of different concepts were identified. As those concepts were identified, some of the technical expectations for what they might be able to provide were also identified.

The notion, I think, that General Abrahamson is referring to is the notion that the technologies that we hope to be able to demonstrate hold the promise for being able to operate in this region of performance levels.

Senator TSONGAS. OK. That is the optimum level. What is the minimum level?

Mr. GARDNER. No, there is nothing optimal about that level, Senator Tsongas. What that is is the region of expectations of where the technology might allow us to operate. It is a region that is related to other defensive systems that have been configured.

Senator TSONGAS. So are you comfortable in saying that we will develop a system in which each of the subparts is 85 percent effective and therefore a 99.99-percent effective total system?

Mr. GARDNER. I am very comfortable in saying that we are undertaking a program in which we would describe goals or performance levels that are that high, or higher. And I am also comfortable that there is a considerable body of scientific evidence assembled last summer, at some considerable effort, that would support those goals. I certainly cannot, at the same time, say that those goals can be realized. We hope to undertake a program that will allow us to determine just how capable a system—it is actually a combination of systems if you think about it—just how capable a combination of systems can be built.

Senator TSONGAS. Would you say a system that is 85 percent effective is any more or less likely than one that is 50 percent effective?

Mr. GARDNER. I can only repeat that the consensus of the technical group was that performance levels in that 85 percent domain were reasonable goals based on our examinations.

Senator TSONGAS. Let me talk about a potential situation in which the Soviets launched and put into place the beginnings of their own SDI or "Star Wars" system. What would be the recommendations, the possible recommendations to the President about what he ought to do about that?

To put it another way, if the Soviets were to launch a counterpart of this system, would it be incumbent upon the United States to shoot it down?

Mr. PERLE. I do not think it is useful or wise, Senator Tsongas, to try to answer what is obviously a very difficult policy question which this country would be confronted with: first, the violation of an existing treaty and second, an act of significance for the securi-

ty of this country, across this hearing table. But we would be glad to think about what we would recommend to the President.

I think the President expects more depth in his recommendations than we can offer you in an instinctive response at this hearing.

Senator TSONGAS. You mean no one has thought about it?

Mr. PERLE. We do not believe that such a move by the Soviets is imminent. We have thought some about how to respond to the Soviet violations of the ABM Treaty which concern us greatly, because it may put the Soviet Union in a position to break out rapidly from the ABM Treaty and deploy a nationwide antiballistic missile defense.

The long leadtime items that we sought to constrain in the ABM Treaty, that is the large-phased array radars, have now been built by the Soviets in significant numbers, the most recent of which is under construction now, in violation of the treaty. So we have begun to think about how to respond to the Soviet acquisition of an ABM capability.

Senator TSONGAS. Well, we do know, according to the testimony earlier, "Were they to deploy the fruits of their programs unilaterally, the consequences to our national security would be exceedingly grave."

Now, you are not suggesting that if something happens that threatens us in a way that is exceedingly grave, that there is not the very serious possibility that the United States would be compelled to go out after it and knock down that system?

Dr. COOPER. That is not true at all, Senator Tsongas. As a matter of fact, a great deal of thought has been given to the question of what the United States should do if the Soviets were to break out of the ABM Treaty, and that is not an inconceivable situation even today.

Senator TSONGAS. Wait a minute. Have you told Mr. Perle that you have been thinking about this?

Mr. PERLE. You asked, I thought, quite a specific question: that is, what would we do if we saw the Soviets launch the first part—we could have the reporter read it back—the first part of what appeared to us to be intended to constitute a strategic defense system in space.

This is a difficult issue on which to give you an immediate answer. I assume that by specifying the first part, you meant to suggest that the opportunity would exist to shoot it down before it could defend itself and, therefore, destroy it at a relatively low risk to the United States.

Senator TSONGAS. I find it very difficult to imagine any President allowing an SDI counterpart to be sitting up there, with all the implications it has for first-strike followup, and not do something about it. And you are not suggesting that an American President would just sit back and let it sit up there?

Dr. COOPER. The technical response to a potential breakout by the Soviets has been well studied, and I believe we understand exactly what we would do, and it has nothing to do with policy; it has to do with the technical response. That is, the question is: What should we do technically to foil the Soviets if they were to begin to break out of the ABM Treaty?

That has been looked at and studied in great detail.

Senator TSONGAS. But there is also a policy decision.

Dr. COOPER. The policy decision is whether to do it or not. It has nothing to do with attacking any Soviet systems. It has to do with a technical response that would preserve the national security interests of this country.

Senator TSONGAS. Wait a minute. If doing it does not mean you attack it, what does "do it" refer to?

Dr. COOPER. The studies that have been done are classified and the responses, the technical responses to a Soviet breakout would have to be discussed in closed session.

General ABRAHAMSON. Sir, let me just address that a little bit. The question is another of the unlikely questions. In real life, we would see, long before they deployed such a system, evidence that they were working on it, and indeed that is the case.

Now, today, we are seeing very significant evidence of an equivalent kind of a research program. What would a response be? It might be people like ourselves sitting here today, saying that it is important for the United States to proceed with a defensive system of our own over a period of time.

Senator TSONGAS. Defensive against their ICBM's or defensive against their SDIs?

General ABRAHAMSON. Defensive against their ICBM's because, after all, all of us are interested in stability as such. What we are finally trying to deal with here is a situation where we have enough assurance and they have enough assurance that it does not make sense to keep large amounts of offensive ballistic missiles around, and therefore we would have a mutual interest in finding ways to support negotiations. Because offensive missiles would be less valuable to us, from both the military point of view, and hopefully an economic point of view as well, we would begin to build-down or reduce the nuclear threat in the world.

After all, that is what this is about.

Senator TSONGAS. Is it possible that the Soviets—let's say they got a 5-year head start on us and developed and deployed an SDI counterpart—that the United States would not shoot it down, but would, rather, begin the R&D and deployment of their own system; in essence, do the Soviets enjoy a 5-year advantage over us?

And if that were the case, if you were a Soviet leader, would you not advise that the best thing to do would be to strike now while you have those systems up there, before we have ours?

Dr. COOPER. Senator, you are creating a completely phantom situation which could not apply. As Jim has pointed out, if the Soviets began to break out, we would certainly see them. It would take them 10 to 20 years to deploy such a system. And it would take us a few years to begin to respond.

So our response, our technical response to an indication that the Soviets were breaking out of the ABM Treaty, has been carefully looked at in a number of different studies, and I think we understand exactly what we would do in that situation.

Senator TSONGAS. How long would it take the United States to deploy its system? The same amount of time?

Dr. COOPER. Certainly 10 to 20 years. As a matter of fact, you could say that for almost any system.

Senator TSONGAS. I am talking about launch deployment.

Dr. COOPER. I am talking about from the time you first see signs in the Soviet Union that they may be doing something and the time that they would have an effective system on orbit, 10 to 20 years.

Senator TSONGAS. Do you believe, if we deployed this system in space, that the Soviets would at least consider the necessity of shooting it down?

Dr. COOPER. I would say that if we decided at some time in the future—say it was 1995 or the year 2000—to do this, that it would take 10 to 20 years to put the system fully in place, and that the Soviets would know about our decision to do that, 10 minutes after the decision had been taken, and they would begin to react to it and respond to it.

Any technology that Jim finally comes up with is certainly apt to deal with their potential to respond. And I am sure that if the Soviets were to deploy any system, they would deploy a system with technology that would be anticipatory of some U.S. response.

Senator TSONGAS. Is it harder to hit a satellite in space or a moving ICBM?

Mr. PERLE. With what?

Dr. COOPER. With what? A rock?

Senator TSONGAS. Well, I hope we are not doing research into that possibility. [Laughter.]

Dr. COOPER. We are very much interested in high velocity kinetic energy weapons of one sort or another.

Senator TSONGAS. Would a lay person's term for that be "rock"?

Mr. PERLE. Or anything else you might throw at the object.

Dr. COOPER. Or anything else you might throw. [General laughter.]

Senator TSONGAS. But given the kinds of systems we are looking at, is there any technical difference in hitting a stationary object in space and an ICBM on launch?

Dr. COOPER. Yes. There is a great difference, and that is the ability to see it, find it, aim at it, and its physical size. A typical ICBM is radiating megawatts of optical power and consequently it is easy to see and find and aim at, whereas a typical satellite may be only radiating tens of watts of optical power, and so it is difficult to find.

Senator TSONGAS. So in terms of technical difficulty, it would be easier to knock out somebody's SDI than it would be for the SDI to knock out an ICBM coming in?

Dr. COOPER. Not necessarily. Clearly, any components that would be deployed in space would have to have the capability to deal with countermeasures, and certainly that is one of Jim's biggest problems, to figure out how—if we are to have systems of this sort in the year 2000—that they can be protected in space from some kind of response from the Soviet Union.

But that is not an impossible thing to do, and as a matter of fact, the research will to a large extent deal with that particular issue.

Senator TSONGAS. Mr. Chairman, I have a number of other questions, but I am obviously not convincing the panel of my point of view. If I could just ask one final question, I would appreciate it.

What is the administration's position on the so-called Tsongas amendment that deals with ASAT's? Are you for the repeal of that amendment?

Mr. PERLE. We think the effect of the amendment would be to grant the Soviets a monopoly in antisatellite capability because the program that it would prevent from going forward is in the U.S. program.

Senator TSONGAS. Would I be off base to conclude from that comment that you are opposed to it?

Mr. PERLE. We do not like the amendment. That is correct.

Senator TSONGAS. So you would be in favor of its repeal?

Mr. PERLE. I would be in favor of removing the restrictions that are entailed in the amendment. Whether repeal is the best way to do that or not remains to be seen.

Senator TSONGAS. Mr. Chairman, let me state that I hope the witnesses who follow will understand the need for us to have gone on at length with this discussion. I would just ask that—I think a lot of technical issues do lend themselves to debate, but I frankly find it very irritating to see sprinkled through the testimony reference to negotiations as a goal, when we will not even sit down and talk.

So if you could just delete that in the future, it would be less irritating and maybe the questions will go on for a shorter period of time.

Thank you, Mr. Chairman.

Senator PRESSLER. Thank you. We have taken more time than perhaps is normal with our first panel. I do have one more question, and I think it is very appropriate that we get all of this on the record, because the Senate will have a major debate on S.J. Res. 129 within the coming month. I think we have to do everything we can to get the information.

I would address one final question to Mr. Perle, if he could give the Administration's position. The OTA study, the No. 1 conclusion or the principal conclusion—and they say that this judgment appears to be the consensus among informed members of the defense technical community—that that conclusion was boiled down to one sentence, and I would like your reaction.

This is my final question. The OTA report says, as its principal judgment, the prospect that emerging "Star Wars" technologies, when further developed, will provide a perfect or near perfect defense system, literally removing from the hands of the Soviet Union the ability to do socially mortal damage to the United States with nuclear weapons, is so remote that it should not serve as the basis of public expectation or national policy about ballistic missile defense.

Mr. PERLE. Frankly, I have not seen the study, which I would presume is an effort to justify that summary conclusion. The sentence, as you read it to me, is rather loosely worded. It talks about damage to the United States, but it reflects only upon strategic defense; and ballistic missiles as only one potential source of damage to the United States, so I find it difficult to evaluate.

But, obviously, we would not be embarking on a research program if we did not think that there were compelling reasons to do so. The hope is that it may lead to a better world, the reality is

that the Soviets are embarked on an aggressive program of their own, and we are not prepared to take the risk of permitting a situation to develop in which they alone come to possess a strategic defense.

So, for a variety of reasons, the administration has embarked on a research program. I do not think it serves the interests of the debate, the proper debate over this question, to describe the program in terms more ambitious, more grandiose, than the decisions that have been made. And the decisions that have been made are research decisions, not deployment decisions, not trillion dollar decisions, but manageable decisions about a research program within manageable budgets. That is the issue before the country, not the question of some ultimate decision about the deployment of a system that does not now exist.

And so I believe that ultimate judgments of the kind represented in that study, or ultimate judgments in general, can only be speculative at this point, and I think we have a profound interest in establishing the facts about what technologies are feasible and where they will lead. I think the alternative is to say we do not want to know. We do not want to find out what potential is there, and by the way, if the Soviets proceed to find out what potential is there, that is a risk we are prepared to take.

That seems to me the implication of much of the legislation, that says we should not even inquire into what the potential is, but we should do nothing to stop the Soviets from inquiring into what the potential is.

Senator PRESSLER. Of course, that is not quite what S.J. Res. 129 says. It does not quite say that it would seek arms control agreements, you might say, to close loopholes in the ABM Treaty such as the one which I believe is currently exploited by the Soviets in building the Krasnayarsk Radar.

Mr. PERLE. There is no loophole under which that radar is being built. That radar is being built in clear circumvention of the treaty.

Senator PRESSLER. Well, shouldn't we close that loophole?

Mr. PERLE. It is not a loophole, Senator. It is a violation. To suggest that it is a loophole is to imply that it is permitted.

Senator PRESSLER. Well then, that violation.

Mr. PERLE. We would very much like to see that violation reversed. We have asked the Soviets to cease construction of that radar, and thus far they have been unwilling to do that. It is hardly surprising, since at the very moment they are in violation of existing treaties, we have committees of the Senate urging that we embark upon new negotiations in areas that are unverifiable. If I were the Soviets, I would not take our representations totally seriously under those circumstances either.

Senator TSONGAS. Mr. Chairman, while you are waiting, if I could just ask Mr. Cooper one more question.

On page 3 of your testimony, you referred to the third test in the ASAT system, subject to satisfying the conditions of the so-called Tsongas amendment would be the first one against an object in space. How would you satisfy the conditions of my amendment? Are you talking about repeal?

Mr. COOPER. Yes. Or some other satisfactory method. And exactly how that is best to be done has left us an open issue.

Senator TSONGAS. So you would satisfy the condition by getting rid of the condition?

Mr. COOPER. That is one way.

Mr. PERLE. There is a problem in the amendment, Senator. As you know, it is our view that a comprehensive ban is unverifiable, and yet the amendment says that as a condition of expenditure for funds for a test against an object in space, we must seek a verifiable treaty.

Now, having concluded that that cannot be accomplished, because we do not know how to verify it, your amendment poses a significant dilemma that you might help us resolve, possibly by altering your amendment.

Senator TSONGAS. The whole purpose was to pose a dilemma for those who do not believe in verification without having first sat down and spoken with the Soviets. I do not see how you can go into court and prove something is not verifiable if you have never at least gone and sat down with the Soviets.

I think it would be a fascinating case to take before the courts to see what happens.

Mr. PERLE. Well, we have heard from the Soviets, and as I indicated earlier, the Soviet position is that verification will be by national technical means only. Now, you may take the view that after protracted negotiation, the Soviets might change their position with respect to national technical means of verification and permit American inspectors to go into the laboratories where they are conducting research on lasers, and the laboratories where they are developing particle beam devices, and their ICBM launch sites, and the storage areas where they might conceivably have concealed a coorbital system. I think that is unlikely in the extreme. And I know deep down, you do, too.

So it seems to me quite pointless to suggest that we chase what is clearly an impossible result. We are far better off concentrating our efforts, it seems to us, in those areas where there is some potential for verification, and we are attempting to do that.

Senator TSONGAS. So there is no possibility of any arms control treaty with the Soviets, either with ASAT's or with "Star Wars," since they all have the same range of difficulty and verification.

Mr. PERLE. Strategic defense is another. We have an existing treaty. That treaty, while there are some verification problems, is not hopelessly unverifiable. We believe that a comprehensive ASAT plan would be hopelessly unverifiable. I do not know that that view has been significantly contradicted.

The argument one most frequently encounters now in recognition of that is that we ought to try for a partial ban, that is, to ban some ASAT systems but not others. And while that issue ought to be investigated——

Senator TSONGAS. Have you proposed that to the Soviets?

Mr. PERLE. No, we have not proposed that to the Soviets.

Senator TSONGAS. Well, have you hinted it?

Mr. PERLE. The first question that needs to be resolved, the policy issue, is whether it makes any sense to enter a negotiation on the elimination of one or two technologies for attacking satellites, while leaving 8 or 10 additional technologies unconstrained,

because in the end you will not have protected the satellites from attack.

It is a mistake, in my judgment, to believe that for every problem there is an arms control solution. There may be some problems that are just intractable with respect to arms control.

Senator TSONGAS. Well, it is also a mistake to believe that there is no solution for any arms control problem.

Mr. PERLE. I do not believe that. I believe that we have put forward——

Senator TSONGAS. Well, name me a treaty you really think was a great treaty.

Mr. PERLE. I do not think we have done very well——

Senator TSONGAS. Cultural exchange?

Mr. PERLE. As a matter of fact, I think the cultural exchange programs with some countries have been enormously successful, and with others rather less successful. But I think we have done rather poorly——

Senator TSONGAS. Well, we have problems with some of those, I guess?

Mr. PERLE. Well, we have a problem with artists—we do not have a problem—the sending states sometimes have a problem with their artists defecting to the United States, which puts a crimp in the program.

Senator TSONGAS. I agree. I think that is a very serious problem—of artists.

Mr. PERLE. But, Senator, as you know—we have talked about this before—I believe that treaties that have led to significant increases in strategic forces have not accomplished the purposes that I think you and I would readily agree are the objectives of arms control. The SALT II Treaty is a treaty that was opposed not only by then candidate Reagan, but by the Senate Armed Services Committee; a sizable margin voted that it was not in the national security interests of the United States.

Senator TSONGAS. Do you think the Senate Armed Services Committee reflects the will of the American people on SALT II?

Mr. PERLE. I think, as I recall the poll data during the ratification debate, it shifted in the course of the debate from a majority favoring it to a majority opposing it, as I recall.

Senator TSONGAS. That is not my recollection. At any rate, I would ask the chairman if he would bring the other witnesses up.

Senator PRESSLER. Let's have a conference, on time, between the two of us. And, I want to thank this panel very much.

General ABRAHAMSON. Mr. Chairman, may I make a request, please? You have asked that several press items—for example, Aviation Week and others—be put into the record. I think that is fine. I think it would also be appropriate if some of the unclassified versions of the Government study on the technological and policy reports associated with the SDI be included in the record as well, and I would request that of you.

Senator PRESSLER. If they are of great length, we will have to summarize them. We do try to limit the page number. How many pages is that? Since it is such an important subject, we will put it in with staff and minority and majority concurrence.

So I very much appreciate that.

[The material referred to follows:]

DEFENSE AGAINST BALLISTIC MISSILES

An Assessment of Technologies and Policy Implications

Department of Defense

MARCH 1984



THE SECRETARY OF DEFENSE

WASHINGTON, THE DISTRICT OF COLUMBIA

Since the dawn of the nuclear age, the United States has sought to preserve peace through deterrence. By making the cost of aggression far greater than any potential gain, the United States has successfully deterred conflict between the major powers for almost four decades.

In the face of an expanding Soviet nuclear arsenal, this Administration has taken steps to strengthen the offensive arm of deterrence while also working for significant, verifiable arms reductions. But President Reagan has also offered the hope of a world made even safer from the threat of nuclear conflict if we could develop defensive systems.

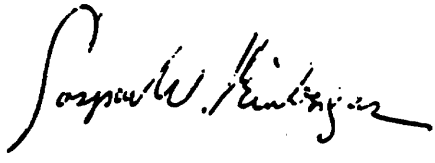
America has always drawn on its technological genius to strengthen its deterrent--both strategic and conventional. And now recent advances in technology offer us, for the first time in history, the opportunity to develop an effective defense against ballistic missiles and the possibility of fulfilling President Reagan's vision of a safer world. Achieving that worthwhile goal will not be easy. For that reason, the analysis provided by the Defensive Technologies Team and the Future Security Team is indispensable.

To carry on the work that those study teams began, the Department of Defense has combined into a single Strategic Defense Initiative previously planned research and development programs in five technology areas. Those areas that offer the greatest promise for an effective defense against ballistic missiles are: surveillance, acquisition, and tracking; directed energy weapons; kinetic energy weapons; systems analysis and battle management; and support programs, such as space electrical power and heavy lift launch vehicles. To the $1.74 billion already planned for research in those five technological areas, the Defense Department has requested an additional $250 million to begin testing weapons lethalty, to research spacecraft survivability, and to exploit other new technological opportunities.

Successful completion of our research programs to determine the most effective defense against ballistic missiles will require the cooperation of many different organizations and all the Military Services. To coordinate all those efforts, the President has directed that we establish a centralized management office within the Department of Defense. The Program Manager will report directly to the Secretary of Defense and will hold frequent reviews to assess progress and make decisions concerning future direction of the Strategic Defense Initiative.

We firmly believe that our research can point out ways to achieve a reliable and effective ballistic missile defense that will enhance deterrence for the United States and our allies. But to succeed in that vital endeavor, we must have the full support of Congress and the American people and wholehearted participation by America's scientists and strategists.

While much remains to be done, we have made a good beginning with these two fine studies. It is vitally important that we continue our efforts to put an end to the threat of nuclear weapons. There can be no winners in a nuclear war. That terrible truth provides the incentive; science provides the opportunity. For the benefit of all mankind, we are committed to seizing that opportunity without delay.



In March 1983, President Reagan offered a hopeful vision of the future based on a program to "counter the awesome Soviet missile threat with measures that are defensive." He said, "we must thoroughly examine every opportunity for reducing tensions and for introducing stability into the strategic calculus of both sides." He spoke of the massive and continuing Soviet buildup of nuclear and nonnuclear forces and of the bleakness of the future before us if we rely solely on the threat of retaliation to deter Soviet attacks against the United States or our allies. The President proposed a strategy that would "significantly reduce any incentive that the Soviet Union may have to threaten attack." He asked, "what if free people could live secure in the knowledge that...we could intercept and destroy strategic ballistic missiles before they reached our own soil or that of our allies?"

The President ordered an assessment of technologies and systems that might provide a defense against ballistic missiles, together with a study of the policy implications of ballistic missile defenses for the United States and our allies. From June through October 1983, these two studies were conducted in close coordination,* and this report is based on them.

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* The study of technologies and systems for ballistic missile defense was conducted by a team of scientists under the direction of Dr. James C. Fletcher. The implications for defense policy, strategy, and arms control were addressed by two study teams: an interagency team of experts led by Mr. Franklin C. Miller and a team of outside experts led by Mr. Fred S. Hoffman.

POLICY IMPLICATIONS OF DEFENSES AGAINST BALLISTIC MISSILES

During the 1950s, the United States maintained substantial programs for defense against possible attack by Soviet bombers. But in the 1960s, in light of the growing threat from Soviet missiles, the United States Government concluded that an effective missile defense would be most difficult to achieve. Moreover, it was thought that deployment would not be desirable because it might provide an incentive for the Soviets to further increase their offensive strategic forces to overwhelm our missile defenses, and that they could do so at a cost much lower than our cost for missile defenses. And once our increasing vulnerability to Soviet missile attacks was accepted, it did not seem warranted to continue a major effort for defense against Soviet bombers. As a result, we largely disbanded our air defenses in the 1960s.

At the same time, a strategic theory gained currency in the United States that held that deterrence of nuclear attack could best be maintained if both the United States and the Soviet Union were vulnerable to attack. This theory found expression in the Anti-Ballistic Missile (ABM) Treaty, which was designed to foreclose widespread deployment of ballistic missile defenses, and in the anticipation that we could reach agreements first to limit and then to reduce strategic offensive forces.

Unfortunately, neither the U.S. abandonment of the attempt to defend against nuclear attack in the 1960s nor the ABM Treaty and the Strategic Arms Limitation Talks (SALT I and II) agreements have led to a leveling off in the growth of offensive systems -- much less to reductions. Moreover, unlike the United States, the Soviet Union has continued to maintain and modernize both a large nationwide air defense system and ballistic missile defenses around its capital (as permitted by the ABM Treaty). In

addition, as the President recently reported to the Congress, the Soviet Union has now deployed a large radar in central Siberia that almost certainly constitutes a violation of legal obligations under the ABM Treaty, since its associated siting, orientation, and capability are prohibited by this Treaty. The Soviets have also been conducting research in technologies that would be required for more effective missile defenses.

The continual growing Soviet offensive threat to the United States and our allies plus the ongoing Soviet research and deployment of defensive systems offers a powerful motive for reassessing the potential role of defensive systems in our security strategy. At the same time, advances in relevant technologies require us to reassess the feasibility of useful defenses. The conjunction of these issues prompted the President to call for a new assessment of the possibilities for increasing the role of defensive systems in our deterrent posture.

It is to be expected that the technological approaches proposed would vary widely in technical risk and strategic uncertainty. For the first time in history, we have the possibility of developing a multitiered system. Such a system could defend against enemy ballistic missiles in all phases of their flight, not only in the terminal phase, where decoys and multiple reentry vehicles (MIRVs) constitute a large number of objects that the defense must cope with. The current technology addresses only the final reentry phase. A capability to intercept missiles in the boost and post-boost phases could defend against a missile attack before the deployment of a multiplicity of reentry vehicles and decoys.

We do not yet have enough information for estimating the entire cost of a full research and development program for a multitiered missile defense. The costs of actual development

of various possible systems will, of course, depend on the characteristics of the systems. Clearly, costs of defenses and the trade-offs with offensive forces they will permit and require are among the most critical issues. The costs will, however, be spread over many years, and decisions on the desired magnitude of the effort can -- and should -- be taken at various stages in the program. At this time, one cannot prejudge the extent to which costs of increasingly more effective defense deployments will be warranted by the resultant security benefits and defense savings in other areas.

The role of ballistic missile defenses must be viewed in the context of the overall military and political requirements of the United States. A decision to pursue ballistic missile defenses would have major implications for nuclear strategy, the prevention of nuclear war, deterrence of aggression, and arms reduction. It is with this broad context in mind that our policy on missile defenses must be shaped. To permit informed decisions we have to conduct research on many aspects of the relevant technology and develop a range of specific choices.

It is likely that components of a multilayered defense, or less than fully effective versions of such a defense, could become deployed earlier than a complete system. Such intermediate versions of a ballistic missile defense system, while unable to provide the protection available from a multitiered system, may nevertheless offer useful capabilities. The development of options to deploy such intermediate capabilities would be an important hedge against an acceleration in the Soviet strategic buildup. If such intermediate systems were actually deployed, they could play a useful role in defeating limited nuclear attacks and in enhancing deterrence against large attacks.

Intermediate defense capabilities would reduce the confidence of Soviet planners in their ability to destroy the high-priority military targets that would probably be the primary objective of a contemplated Soviet attack. The planners' decreased confidence in a successful outcome of their attacks against military targets, war-supporting resources within the United States, or U.S. and allied forces overseas would strengthen deterrence of Soviet use of nuclear arms.

An effective, fully deployed U.S. ballistic missile defense could significantly reduce the military utility of Soviet preemptive attacks, thereby potentially increasing both deterrence and strategic stability. But such a defense could remain effective only if the Soviet Union could not negate it with countermeasures more cheaply than the United States could maintain the viability of the system, or if the two sides agreed to limit offensive missile forces while protecting defensive systems. Effective defenses strengthen deterrence by increasing an attacker's uncertainty and undermining his confidence in his ability to achieve a predictable, successful outcome. By constraining or eliminating the effectiveness of both limited and major attack options against key U.S. military targets and thus leaving only options for attacking urban areas -- which would be of highly questionable credibility -- defenses could significantly reduce the utility of strategic and theater nuclear forces and raise the threshold of nuclear conflict.

It must be recognized, however, that there are uncertainties that will not be resolved until more is known about the technical characteristics of defensive systems, the future arms policies of the Soviet Union, the prospects for arms reduction agreements, and the Soviet response to U.S. initiatives. Important questions to be addressed are: (1) the absolute and relative effectiveness of future U.S. and Soviet defensive systems and how this

effectiveness is perceived by each side; (2) the vulnerabilities of the defensive systems (both real and perceived); (3) the size, composition, and vulnerabilities of each side's offensive forces; and (4) the overall U.S.-Soviet military balance. While these uncertainties cannot be fully resolved, we will learn more about them with the passage of time. Our assessment of these issues will affect design and deployment decisions.

These uncertainties notwithstanding, a vigorous R&D program is essential to assess and provide options for future ballistic missile defenses. At a minimum, such a program is necessary to ensure that the United States will not be faced in the future with a one-sided Soviet deployment of highly effective ballistic missile defenses to which the only U.S. answer would be a further expansion of our offensive forces ("penetration aids," more launchers, etc.). Such a situation would be fraught with extremely grave consequences for our security and that of our allies. There is no basis for the assumption that decisions on the deployment of defensive systems rest solely with the United States. On the contrary, Soviet history, doctrine, and programs (including an active program to modernize the existing Moscow defense -- the only operational ballistic missile defense in existence) all indicate that the Soviets are more likely (and better prepared) than we to initiate such a deployment whenever they deem it to their advantage. For the near future, in particular, they are better prepared than we to deploy traditional ("conventional") terminal defenses. U.S. work on ballistic missile defense technology in the 1960s and early 1970s appears to have been an important factor in Soviet willingness to agree to the deployment limits imposed by the ABM Treaty; similar considerations can be expected to play a role in future Soviet decisions on the deployment of ballistic missile defenses.

If U.S. research efforts on defensive technologies prove successful, and are so perceived by the Soviet Union, such

technologies could fundamentally alter the nature of the strategic relationship between the United States and the Soviet Union. Advanced ballistic missile defenses have the potential for reducing the military value of ballistic missiles and lessening the importance of their role in the strategic balance. In reducing the value of these weapons, defensive technologies could substantially increase Soviet incentives to reach agreements reducing nuclear arms. In conjunction with air defense and effective, agreed constraints on all types of offensive nuclear forces, highly effective ballistic missile defenses could drastically diminish the threat of massive nuclear destruction.

Nevertheless, the immediate response of the Soviet Union to a U.S. effort to develop ballistic missile defenses is likely to be a continuation of its current political and diplomatic campaign to discredit such defenses. At the same time, the Soviet Union will continue its own efforts on air defenses and on both existing and advanced ballistic missile defenses. The Soviets can also be expected to press ahead with further expansion and modernization of their offensive systems. The Soviets may change their pattern of behavior if they become convinced that the American commitment to the deployment of defenses is serious, that there are good prospects for eventual success in the development of ballistic missile defenses, and that such deployments present opportunities for a safer U.S.-Soviet nuclear relationship.

Since long-term Soviet behavior cannot reliably be predicted, we must be prepared to respond flexibly. A research and development program on ballistic missile defense that provides a variety of deployment options will help resolve the many uncertainties we now confront and over time offers the United States flexibility to respond to new opportunities. By contrast, without the research and development program,

we condemn future U.S. Presidents and Congresses to remain locked into the present exclusive emphasis on deterrence through offensive systems alone.

If, for example, the Soviets persisted in attempts to expand their massive offensive forces, a flexible research and development program would force Soviet planners to adopt countermeasures, increasing the costs of their offensive buildup and reducing their flexibility i.. designing new forces in a manner that they would prefer. Over time, our research and development on ballistic missile defense might induce a shift in Soviet emphasis from ballistic missiles, with the problems they pose for stability, in favor of air-breathing forces with slower flight times. By constraining Soviet efforts to maintain offensive forces and making them more costly, U.S. options to deploy ballistic missile defenses might increase our leverage in inducing the Soviets to agree to mutual reductions in offensive nuclear forces. In turn, such reductions could reinforce the potential of defensive systems to stabilize deterrence. Reductions of the magnitude proposed by the United States in the Strategic Arms Reduction Talks (START) would be very effective in this regard.

In its initial stages, a U.S. ballistic missile defense research and development program would be consistent with existing U.S. treaty obligations. Were we to decide on deployment of a widespread defense of the United States, the ABM Treaty would have to be revised. If the results of the research and development program warranted such a decision in the future, it would be appropriate to address it in the context of a joint consideration of offensive and defensive systems. This was the context contemplated at the outset of the SALT negotiations; but while we reached an agreement limiting defenses, our anticipations of associated limitations on offensive forces have not yet been realized.

Both the Soviet national interest and traditional themes in Soviet strategic thought give reason to expect that the Soviets will respond with increased dependence on defensive forces relative to offensive forces. The nature of a cooperative transition to defensive forces would depend on many factors, including the technical aspects of each side's defensive systems, their degree of similarity or dissimilarity, and whether U.S. and Soviet systems would be ready for deployment in the same period. Because of the uncertainties associated with these factors, no detailed blueprint for arms control in the transition period can be drawn at this time. A list of arms control measures might include agreed schedules for introducing the defensive systems of both sides, and associated schedules for reductions in ballistic missiles and other nuclear forces. Confidence-building measures and controls on devices designed specifically to attack or degrade the other side's defensive systems are other potential arms control provisions.

If both the United States and the Soviet Union deployed defensive systems against a range of nuclear threats, it would not diminish the need to strengthen U.S. and allied conventional military capabilities. Moreover, to realize the protection offered by a fully effective strategic defense, we would require air defenses so that the ballistic missile defense could not be circumvented by increased deployments of bombers and cruise missiles. The integration of defenses against air-breathing vehicles with defenses against ballistic missiles requires further study.

Defense against ballistic missiles offers new possibilities for enhanced deterrence of deliberate attack, greater safety against accidental use of nuclear weapons or unintended nuclear escalation, and new opportunities and scope for arms control. The extent to which these possibilities can be realized will depend on how our present uncertainties about technical feasibility, costs, and Soviet response are resolved. Clearly, the pursuit of defensive systems should not build only on our present policies of maintaining peace; it should also seek to strengthen the effectiveness of our strategic policy in the face of a growing Soviet threat. The essential objective of the U.S. strategic defense initiative is to diminish the risk of nuclear destruction -- contrasted with continued, sole reliance on the threat of nuclear retaliation -- to provide for a safer, less menacing way of preventing nuclear war in the decades to come.

TECHNOLOGIES FOR DEFENSE AGAINST BALLISTIC MISSILES

Six broad areas were addressed by the technologies study team: (1) surveillance of Soviet missile forces and acquisition and tracking of missile attacks; (2) directed energy weapons for missile defense; (3) more-conventional weapons for missile defense; (4) the control and coordination of the battle between the offensive missile forces and our defenses, together with its requirements for communications and data processing; (5) concepts for an integrated defensive system; and (6) possible Soviet countermeasures and tactics.

The goal of the study was to provide guidance for research and development programs, in particular for the development of technologies that could make possible a defense against ballistic missiles. As a first step, the research and development program should further informed decisions on subsequent engineering programs seeking to test the technologies.

In addition, the study identified demonstrations of key components of a missile defense that could be conducted by the end of this decade. These demonstrations can provide a basis for choosing specific, partial missile defense systems to be deployed by the early 1990s. Such partial systems could defend perhaps a few critical targets, especially against smaller attacks. In the event of a large missile attack, however, many missiles would reach their targets. Yet even the limited effectiveness of a partial system could make a significant contribution to deterrence by depriving the enemy planner of reliable military results of his attack.

This study dealt only with defenses against ballistic missiles; defenses against bombers and cruise missiles have been evaluated in other studies.

The principal conclusions of this study were that:

- o New technologies for ballistic missile defense hold promise that warrants a major research and development effort to provide specific options for defensive systems.

- o Through demonstration projects, evidence and measurement of progress on the required technical capabilities can be provided within the next ten years.

- o Development of all the technologies essential for a comprehensive ballistic missile defense will require effective coordination through central management for the research and development efforts.

- o The most effective defensive systems have multiple layers, or tiers.

- o A combination of technologies and special tactics needs to be developed to protect vulnerable components of the future defense system.

A. THE BALLISTIC MISSILE ATTACK

Advances in Soviet and U.S. technology warrant a reevaluation of ballistic missile defenses. Over the past twenty years, the Soviet threat from ballistic missiles has increased steadily. For purposes of analysis, this study assessed a variety of potential future threats, ranging from an attack with fewer than 100 ballistic missiles and a few hundred warheads to an attack with thousands of missiles launched simultaneously with tens of thousands of warheads. The study focused on the most demanding

case -- a ballistic missile attack, unconstrained by arms limitations, that would impose the greatest stress on a defensive system.

In seeking to determine the best defense, the study team analyzed the characteristics of a ballistic missile throughout all four phases of a typical trajectory (Fig. 1). In the boost phase, the first- and second-stage engines of the missile are burning, producing intense infrared radiation that is unique. A post-boost, or bus deployment, phase occurs next, during which multiple warheads and enemy "penetration aids" are released from a missile. (Penetration aids are objects that accompany a missile attack, designed to saturate defenses.) Next, in the midcourse phase, warheads and penetration aids travel on ballistic trajectories above the atmosphere. In the final phase, the warheads and penetration aids reenter the atmosphere, where they are affected by atmospheric drag.

B. CHARACTERISTICS OF AN EFFECTIVE DEFENSE AGAINST BALLISTIC MISSILES

1. Defense in Depth

For many years now, ballistic missile defense studies and experiments have continued to support the conclusion that an efficient defense against large missile attacks would need to be multitiered. Some missiles (or other objects that are part of the attack) will be able to penetrate any one defensive tier; those that have not been intercepted at one phase will move on to the next phase. For example, a 10 percent "leakage" in each of three tiers would amount to an overall leakage of only 0.1 percent. A single layer that can achieve 90 percent effectiveness is many times less costly than a single layer of 99.9 percent effectiveness. It is thus reasonable to construct a three- or four-layer defense with 99.9 percent effectiveness at far less cost than that of the equivalent single-layer defense. Finally,

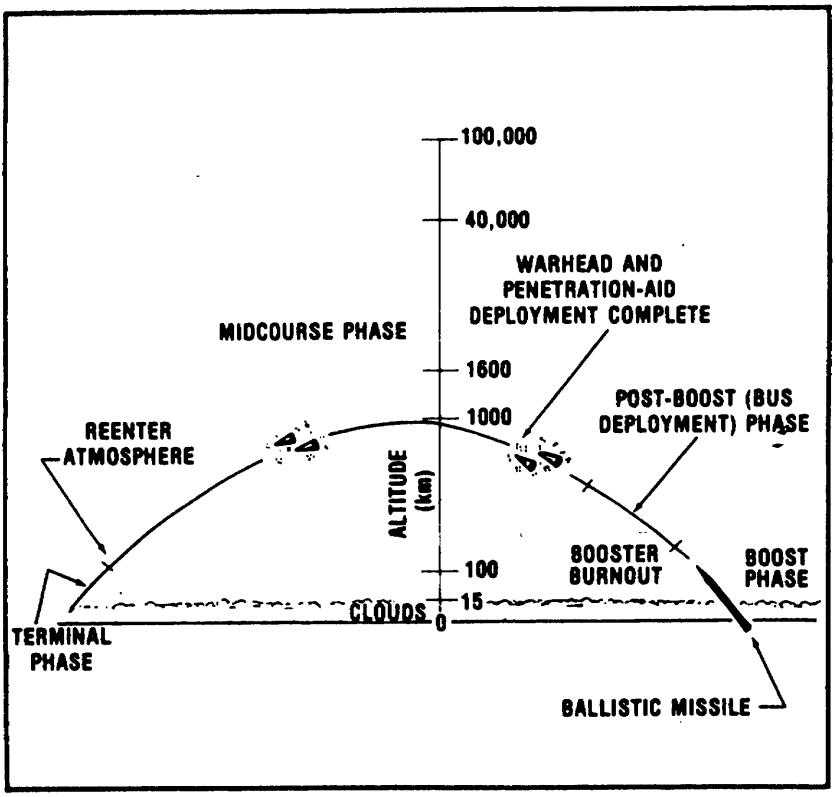


Figure 1: Phases of a typical ballistic missile trajectory. During the boost phase, the rocket engines accelerate the missile payload through and out of the atmosphere and provide intense, highly specific observables. A post-boost, or bus deployment, phase occurs next, during which multiple warheads and penetration aids are released from a post-boost vehicle. In the Midcourse phase, the warheads and penetration aids travel on trajectories above the atmosphere, and they reenter it in the terminal phase, where they are affected by atmospheric drag.

a multitiered defense complicates an attacker's planning because any single method an attacker used to circumvent the defensive system would not be equally effective for each tier. This compounds the uncertainty of Soviet planners about the effectiveness of a missile attack that they might contemplate.

2. Defense at Each Tier

The effective reach of a terminal-defense interceptor is determined by how fast it can fly and how early it can be launched. Terminal-defense interceptors fly within the atmosphere. The precise timing of their launching is linked to discrimination of their real targets from penetration aids and accompanying debris. Terminal defense must be complemented by area defenses that intercept incoming warheads at long ranges. Intercepts outside the atmosphere, designed to eliminate threatening warheads while they are still in the midcourse trajectory, offer such a complement. Figure 2 illustrates one of many possible concepts for terminal-phase intercept. New technologies make it possible to perform these intercepts with nonnuclear warheads.

Midcourse intercept requires the defense to identify decoys designed precisely to attract interceptors and exhaust the defending force prematurely. Fortunately, in this phase, there is more time available than at later stages to engage objects in trajectory. The midcourse defensive system must provide both early filtering, or discrimination, of nonthreatening objects and continuing warhead attrition to minimize the demand placed on the terminal system. Placing a layer of defense intercept before midcourse is an attractive option. To delay the start of the defensive effort until midcourse would accept the risk of a large increase in the number of objects the defense must cope with because multiple independently targeted reentry decoys would have been deployed. Figure 3 illustrates one of many possible concepts for midcourse-phase intercept.

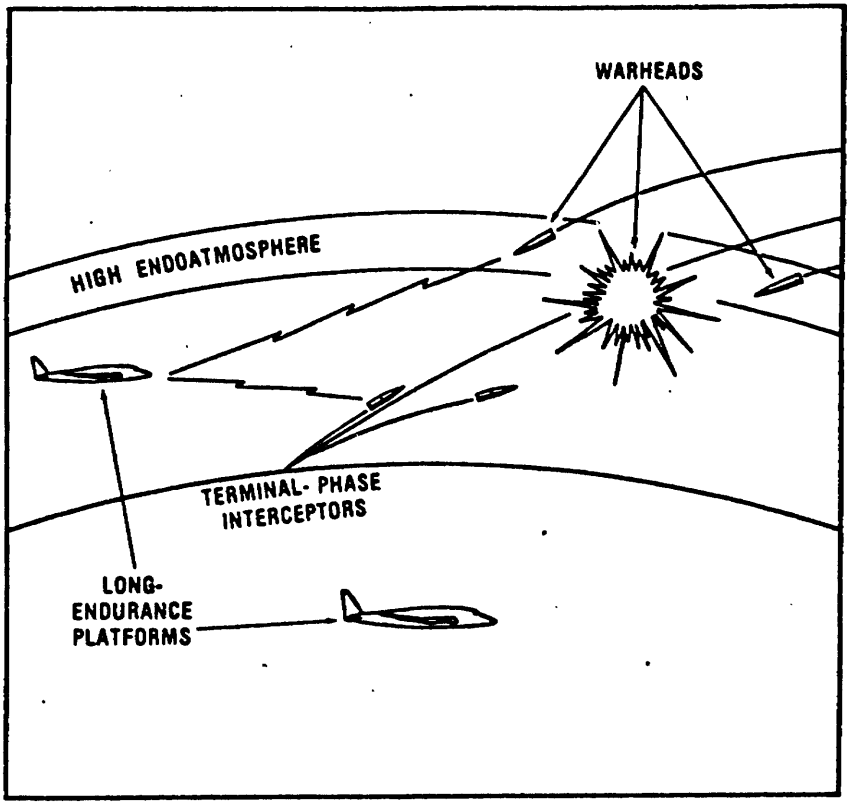


Figure 2: Strawman concept for ballistic missile defense during the terminal phase. This phase is the final line of defense. Threatening objects include warheads shot at but not destroyed, objects never detected, and decoys neither discriminated nor destroyed. These objects must be dealt with by terminal-phase interceptors. An airborne optical adjunct is shown here. Reentry vehicles are detected in late exoatmospheric flight with sensors on these long-endurance platforms. The interceptors - nonnuclear, direct-impact projectiles - are guided to the warheads that survived the engagements in previous phases.

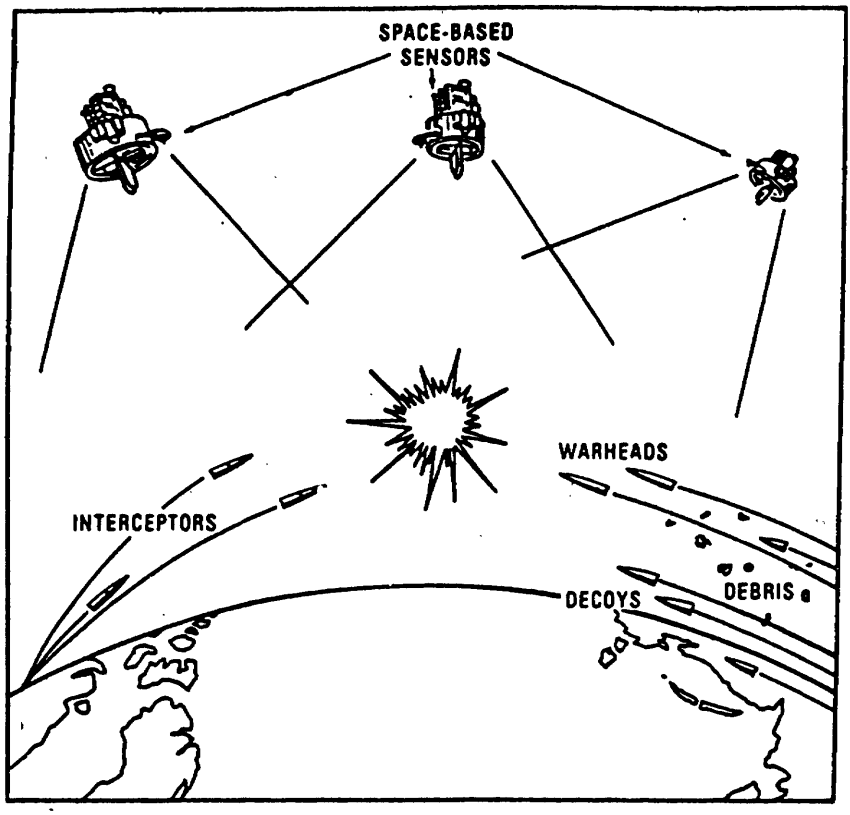


Figure 3: Strawman concept for ballistic missile defense during the midcourse phase. Intercept outside the atmosphere during the midcourse phase requires the defense to cope with decoys designed to attract interceptors and exhaust the defending force. Continuing discrimination of nonthreatening objects and continuing attrition of reentry vehicles will reduce the pressure on the terminal-phase system. Engagement times are longer here than in other phases. The figure shows space-based sensors that discriminate among the warheads, decoys, and debris and the interceptors that the defense has committed. The nonnuclear, direct-impact projectiles speed toward warheads that the sensors have identified.

In the post-boost phase, the defense must cope with an increasing number of objects in the enemy attack, as decoys and reentry vehicles are deployed. On the other hand, the post-boost phase offers additional time for interception, and an opportunity to discriminate between warheads and deception objects as they are deployed. Figure 4 illustrates one of many possible concepts for boost-phase and post-boost-phase intercept.

Consequently, an ability to defend effectively against large Soviet missile attacks would be strongly dependent on the effectiveness of a boost-phase intercept system. For every booster destroyed, the number of objects to be identified and sorted out by the remaining elements of a layered ballistic missile defense system is reduced sharply. Because each booster is capable of deploying tens of reentry vehicles and hundreds of decoys, the defense, by destroying the boosters, has to destroy 1 percent or less of the objects it would have to cope with in subsequent phases of the missile trajectory--truly substantial leverage. Yet a boost-phase system is itself constrained by the very short time during which the target can be engaged and the potentially large number of targets. Because of these constraints, and because of the need to obtain the maximum leverage from all tiers of the strategic defensive system, we need an effective system for surveillance and for commanding and allocating the defenses against a missile attack ("battle management").

Each phase in the layered defensive system presents different technical challenges. But in each phase, a defensive system must perform three basic functions: first, surveillance, acquisition, and tracking; second, intercept and target destruction; and third, battle management.

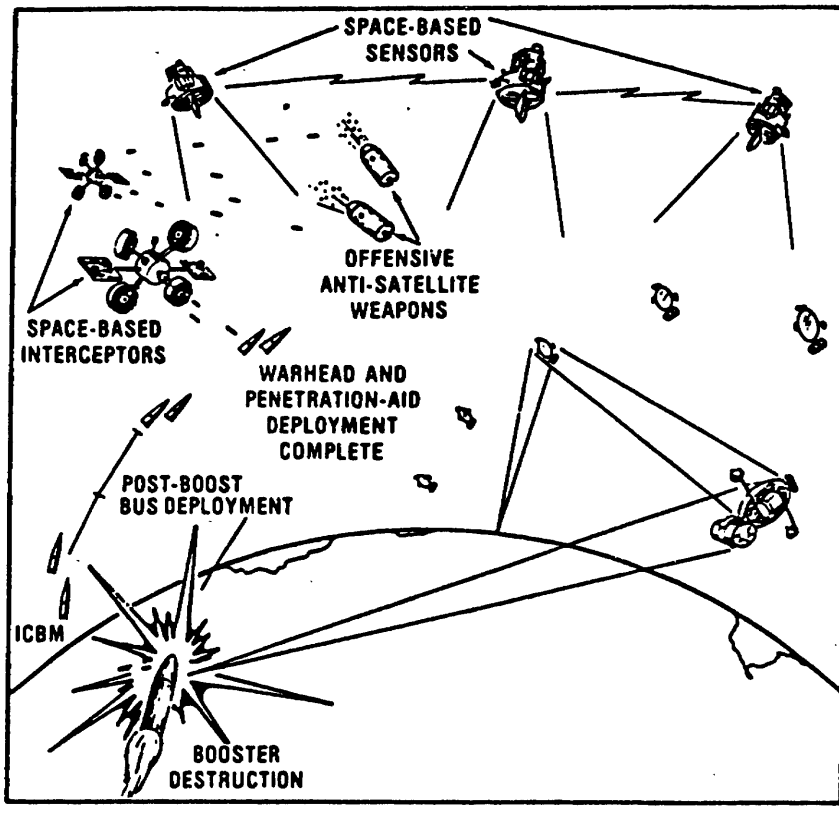


Figure 4: Strawman concept for ballistic missile defense during the boost-phase. An essential requirement is a global, full-time surveillance capability to detect an attack and define its destination and intensity, determine targeted areas, and provide data to guide boost-phase intercept and post-boost vehicle tracking systems. Attacks may range from a few missiles to a massive, simultaneous launch. For every booster destroyed, the number of objects to be identified and sorted out by the remaining elements of a multitiered defense system will be reduced significantly. An early defensive response will minimize the numbers of deployed penetration aids. The transition (post-boost phase) from boost phase to midcourse allows additional time for intercept by boost-phase weapons and for discrimination between warheads and deception objects. Space-based sensors detect and define the attack. Space-based interceptors protect the sensors from offensive anti-satellite weapons and, as a secondary mission, attack the missiles. In this depiction nonnuclear, direct-impact projectiles are used against the offensive weapons.

C. KEY FUNCTIONS OF A BALLISTIC MISSILE DEFENSE

A ballistic missile defense capable of engaging the missile attack all along its flight path must perform certain functions:

- Promptly and reliably warn of an attack and initiate the defense. Global, full-time surveillance of ballistic missile launch areas is required to detect an attack, define its destination and intensity, and provide data to guide boost-phase intercept and post-boost tracking systems.

- Continuously track all threatening objects from the beginning to the end of their trajectories. This objective would allow accurate and timely data transfer from tracking systems to intercept systems, permitting the assignment of intercepts to attacking reentry vehicles.

- Efficiently intercept and destroy the booster or post-boost vehicle. The defense must be capable of dealing with attacks ranging from a few dozen missiles to a massive, simultaneous launch. An early attack on post-boost vehicles will minimize the number of penetration aids deployed.

- Efficiently discriminate between enemy warheads and decoys through filtering of lightweight penetration aids. The system must be capable of rapidly and effectively discriminating decoys or penetration aids from reentry vehicles (warheads). The more effective such discrimination, the greater the cost to the offense in providing the necessary mass and volume for decoys that cannot be filtered out.

- Low-cost intercept and destruction in midcourse. Accurate recognition of the enemy warheads (reentry vehicles) in this phase and a capability to intercept them cheaply will increase the enemy's difficulty and cost in mounting an effective attack. To discourage the Soviet Union from increasing the number of warheads, the cost to the U.S. defense for interceptors should be less than the cost to the Soviet offense for warheads.

- Terminal intercept at the outer reaches of the atmosphere and destruction. The final phase involves the relatively short-range intercept of each reentering warhead.

- Battle management, communications, and data processing. These are the connecting elements that coordinate all system components to gain effectiveness and economy of force.

D. THE EFFECT OF ADVANCES IN DEFENSE TECHNOLOGIES

Because of recent advances in technology, it is now possible to specify how these key functions of an effective ballistic missile defense could be met. For example, two decades ago no reliable means for boost-phase intercept were known. Now, several approaches are becoming feasible for boost-phase defenses, based on directed energy concepts (such as particle beams and lasers) and methods for destroying enemy missiles based on kinetic energy (including nonnuclear rocket-propelled projectiles and hypervelocity guns).

Twenty years ago, midcourse intercept was difficult. No credible concepts for decoy discrimination existed, the intercept cost was high, and the unintended damage caused by nuclear weapons then necessary for the interceptor warheads was unacceptable. Today, multispectral sensing of incoming objects with

laser imaging and millimeter-wave radar, tracking through all phases of the trajectory, and inexpensive direct-impact projectiles give promise of overcoming the difficulties of midcourse intercept.

A few years ago, it was not yet possible to design a method to differentiate between penetration aids and warheads at high altitudes. This shortcoming, combined with limited interceptor performance, meant that an effective defense would have required too many interceptors. Now, technological advances provide new ways to discriminate among multiple incoming objects, as well as to intercept missiles at high altitudes. Coupled with an ability to intercept enemy missiles and warheads in boost phase and midcourse and to disrupt coordinated enemy attacks, these improvements would greatly increase the effectiveness of terminal defenses.

But it is not sufficient to develop the capability to destroy incoming targets without also developing the capability to manage the allocation of interceptors and their integration with other portions of a multitiered defense system. Computer hardware and software and signal processing in the 1960s was incapable of supporting such a multitiered defense battle management. Today, technological advances permit the development of effective command, control, and communications facilities.

New technology also offers more effective solutions to the problem of discriminating between a warhead and a decoy or debris. By using both active and passive sensors, a ballistic missile can be observed during its trajectory to determine the presence of a warhead. An active sensor determines the location and motion of the object by measuring radiation that has been directed from the sensor to the object and reflected from the object back to the sensor; a passive sensor relies on radiation

emanating from the object. Active techniques, such as creating an observable thermal response by an object to a continuous-wave laser, and passive techniques, such as observing with infrared sensors, are possible ways to improve surveillance, acquisition, and tracking of missiles. Both active and passive surveillance techniques are being developed to image an object in order to determine by its appearance what it is. It is important to understand that any one sensor can be defeated, but it is far more difficult to defeat several operating simultaneously.

E. THE NEW TECHNOLOGIES

1. Surveillance, Acquisition, and Tracking

As each potential reentry vehicle begins ballistic midcourse flight accompanied by deployment hardware (or "space junk") and possibly by decoys, every object must be evaluated and accounted for from the beginning to the end of the trajectory, even if the price is many wasted evaluations about what are, in effect, decoys. Defending interceptor vehicles must also be tracked to maintain a complete and accurate status of the engagement.

Midcourse sensors must be able to discriminate between warheads that survive through the post-boost deployment phase and nonthreatening objects such as decoys and debris. They must also provide warhead position and trajectory data to permit timely and accurate employment of interceptors and to assess target destruction. The minimum requirements are to track all objects designated as reentry vehicles, and also to track other objects that might be confusing in later tiers.

Space-based, passive infrared sensors could provide the means to meet this tracking requirement. They could permit

long-range detection of warheads (or cold objects) against the space background and the elimination of simple, lightweight objects, leading to determination of the full trajectories of threatening objects. Laser trackers could also provide validation to determine if targets had been destroyed, as well as precision tracking of objects as they continue through midcourse. As the objects proceeded along their trajectories, data would be handed off from sensor to sensor and the computerized tracking files progressively improved.

For the final line of the defense, the surveillance and tracking would be based, where possible, on the data collected from the midcourse engagement. This task would consist of the sorting of all objects that have leaked through the early defense layers to identify the remaining enemy reentry vehicles. Objects to be tracked would include reentry vehicles shot at but not destroyed, reentry vehicles hitherto undetected, and decoys and other objects that were neither identified nor destroyed. These possible threatening objects must be assigned to final-phase interceptors.

One innovative concept for that phase involves an airborne optical adjunct--a platform put into position on warning of attack--that would help detect arriving reentry vehicles using infrared sensors (much as space-based sensors had done in midcourse), tracking those not previously selected. Airborne sensors could also provide data necessary for additional discrimination. They could acquire and track objects as they were about to reenter the atmosphere and observe interactions of those objects with the atmosphere from the beginning of reentry. At that point, a laser or radar would precisely measure the position of each object and refine its track before interceptors would be committed.

2. Intercept and Destruction of Threatening Objects

A variety of mechanisms, including directed energy, can destroy an object at any point along its trajectory. The study identified several promising possibilities. A laser relying on advanced technology can be designed to produce a single giant pulse that delivers a shock wave to a target. The shock causes structural collapse. A continuous-wave or repetitively pulsed laser delivers radiant thermal energy to the target. Contact is maintained until a hole is burned through the target or the temperature of the entire target is raised to a damaging level. Examples of such lasers are free-electron lasers, chemical lasers (hydrogen fluoride or deuterium fluoride), and repetitively pulsed excimer lasers.

There are other possible means of destroying incoming warheads. A neutral-particle beam could deposit sufficient energy within a missile or warhead to destroy its internal components. In conventional warfare, guns and missiles destroy their targets through kinetic-energy impact supplemented with a chemical explosive in some cases. In defending against ballistic missiles, homing projectiles propelled by chemical rockets or by hypervelocity guns, such as the electromagnetic gun based on the idea of an open solenoid, could destroy warheads in all phases.

3. Battle Management

The tasks of battle management are (1) to monitor the global situation, (2) to allocate all available defense weapons (interceptors, etc.), (3) to determine their best use, and (4) to report results.

A layered battle-management system would correspond to the different layers of the ballistic missile defense system, each

layer being semiautonomous, with its own processing resources, rules of engagement, sensor inputs, and weapons. During an engagement, data would be passed from one phase to the next. The exact system architecture would be highly dependent on the mix of sensors and weapons, and the geographical scope of the defense to be managed would determine the structure of the battle-management system.

As sensors survey the field of battle, raw data are filtered to reduce the volume. Later processes organize these data according to (1) the size of the object, (2) orbital parameters and positions as a function of time, and (3) listings of other data that help identify and assess the threat inherent in the object that is being tracked. In principle, all objects in the field of view of the sensors are candidates for tracking, and all objects that cannot readily be rejected as nonthreatening would appear in the file--the representation of the total battle situation.

Defense system resources include sensors and weapons, the data-processing and communication equipment, and the platforms (or "stations") on which these and other components are emplaced. The assignment of these resources--both sensor and weapon--is a dynamic process requiring reexamination throughout an engagement. For example, sensors must be assigned to sectors or to targets of interest at appropriate times to acquire necessary targeting and tracking data. Weapons must then be assigned to targets as determined by rules of engagement. Defensive resources must extrapolate the present situation into the future to determine the most likely development of the attack and to select a course of action that maximizes the effectiveness of the defense.

F. MEETING THE CHALLENGE

The Technologies Study concentrated on the most difficult aspects of a multitiered, four-phase ballistic missile defense system capable of defending against a massive threat--the technologies that pose the greatest challenge. The study team was primarily concerned with technologies whose feasibility would determine whether an effective defense is indeed possible.

1. Critical Technologies

Several critical technologies will probably require research and development programs of ten to twenty years to be ready for deployment as part of such a ballistic missile defense.

- o Boost and post-boost-phase intercept. As mentioned earlier, the ability to respond effectively to a very large missile attack is strongly dependent on countering it during the boost or post-boost phases.

- o Discrimination. Dense concentrations of reentry vehicles, decoys, and debris must be identified and sorted out during the midcourse and high reentry phase.

- o Survivability. A combination of tactics and mechanisms to ensure the survival of the system's space-based components must be developed.

- o Interceptors. By using inexpensive interceptors in the the midcourse and early reentry phase, intercept can be sufficently economical to permit attacks on objects that may not be warheads.

- Battle Management. Tools are needed for developing battle-management software.

There is much still to be done. For example, the management of large computer systems will pose important challenges. Developing hardware will not be as difficult as developing appropriate software. Large packages of software (on the order of 10 million lines of code) for reliable, safe, and predictable operation would have to be deployed. Fault-tolerant, high-performance computing would be necessary. Not only must it be maintenance-free for many years, but it must also be radiation-hardened, able to withstand substantial shock, and designed to avoid a sudden failure of the entire computer system. The management of interlocking networks of space-, air-, and ground-based resources would require the development an accurate means of transferring data between computer systems rapidly and accurately, through system-generated protocols. There must also be a means to reconstitute all or part of the system if portions of it are damaged or made inoperable. In addition, specific ballistic missile defense algorithms will have to be developed for target assignment and a simulation environment for evaluating potential system architectures.

The problem of survivability is particularly serious for space-based components. The most likely threats to the components of a defense system are direct-ascent anti-satellite weapons, ground- or air-based lasers, orbital anti-satellites, both conventional and directed energy weapons, space mines, and fragment clouds. On the ground, traditional methods to enhance survivability can be effective, such as hardening, evasion, proliferation, deception, and active defense. But to protect space-based systems, these methods must be employed in combination. Ideally, the defense system should be designed to withstand an attack meant to saturate the system. At the very least, the system's most critical points must be protected.

The history of warfare in general and the interactions of weapons technologies in particular indicate that for many potentially successful defenses counters have been developed. It is essential, therefore, to consider possible countermeasures to the development of a ballistic missile defense. But countermeasures are likely to compete with other military programs for available resources and thus may result in diminished offensive capability. For example, hardening of booster rockets of missiles (to withstand a boost-phase missile defense) results in either a reduced payload or a shorter range of the offensive missiles.

2. Logistical Support

The study also described research programs on space logistics that would take five to ten years to complete. In order of priority, the requirements are: (1) development of a heavy lift launch vehicle for space-based platforms of up to 100 metric tons (220,000 pounds one-time payload); (2) ability to service the space components; (3) ability to make available, or to orbit, sufficient materials for space-component shielding against attack; (4) ability to transfer items from one orbit to another; and (5) multimegawatt power sources for space applications.

Based on the Defensive Technologies Study, the Department of Defense, along with the Department of Energy, has established a new program for the President's Strategic Defense Initiative (SDI). Existing programs relating to the SDI have been focused in five technology areas, and additional funding will be sought to pursue them aggressively. In recognition of its importance, the Strategic Defense Initiative will be centrally managed and will report directly to the Secretary of Defense.

The Strategic Defense Initiative represents one of the most important technological programs the Nation has ever embarked upon--a great hope for the future--but it does not represent a deployment attempt, nor is it a substitute for current strategic and conventional force modernization or for arms control. Rather, it will create the technological base for sound deployment decisions. SDI will use America's greatest assets, our creativity and our ingenuity, to lessen the awesome threat of nuclear weapons.

BALLISTIC MISSILE DEFENSES AND U.S. NATIONAL SECURITY

SUMMARY REPORT

Fred S. Hoffman, *Study Director*

October 1983

Prepared for the

FUTURE SECURITY STRATEGY STUDY

FSSS

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Acknowledgments

This report is a summary of work performed by a Study Team whose members were: Mr. Fred S. Hoffman, Director; Mr. Leon Sloss, Deputy Director; Mr. Fritz Ermarth; Mr. Craig Hartsell; Mr. Frank Hoeber; Dr. Marvin King; Mr. Paul Kozemchak; Lt. Gen. C. J. LeVan, USA (Ret.); Dr. James J. Martin; Mr. Marc Millot; Mr. Lawrence O'Neill; and Dr. Harry Sauerwein. The work of the Study Team has been reviewed by a Senior Policy Review Group consisting of Professor John Deutch; Dr. Charles Herzfeld; Mr. Andrew W. Marshall; Dr. Michael May; Professor Henry S. Rowen; General John Vogt, USAF (Ret.); Ambassador Seymour Weiss; Mr. Albert Wohlstetter; and Mr. James Woolsey. Supporting papers have been contributed by Mr. Craig Hartsell, Dr. James J. Martin, Mr. John Baker, Lt. Gen. C. J. LeVan, Mr. Douglas Hart, Mr. Marc Millot, Dr. David S. Yost, Mr. Leon Sloss, and Mr. Frank Hoeber.

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Responsibility for the views expressed herein rests with the Study Team.

Preface

President Reagan has directed an "effort to define a long-term research and development program...to achieve our ultimate goal of eliminating the threat posed by strategic nuclear missiles...." The President noted that the achievement of the ultimate goal was a "formidable technical task" that would probably take decades, and that "as we proceed we must remain constant in preserving the nuclear deterrent...maintaining a solid capability for flexible response...pursue real reductions in nuclear arms...(and) reduce the risk of a conventional military conflict escalating to nuclear war by improving our nonnuclear capabilities."

Two studies assisted in that effort: (1) the Defensive Technologies Study (DTS) to review the technologies relevant to defenses against ballistic missiles and recommend a specific set of long-term programs to make the necessary technological advances, and (2) the Future Security Strategy Study (FSSS) to assess the role of defensive systems in our future security strategy. The implications for defense policy, strategy, and arms control were addressed by two FSSS teams: an interagency team led by Mr. Franklin C. Miller, and a team of outside experts led by Mr. Fred S. Hoffman. This is a report on the results of the work of the team of outside experts. The work was done under the auspices of the Institute for Defense Analyses at the request of the Office of the Under Secretary of Defense for Policy to assist the interagency team.

This report and its conclusions do not necessarily represent the views of the Department of Defense or the Institute for Defense Analyses.

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SUMMARY REPORT

A. MAJOR CONCLUSIONS AND RECOMMENDATIONS

The Strategic Need for Defensive Systems

1. *U.S. national security requires vigorous development of technical opportunities for advanced ballistic missile defense systems.*

- Effective U.S. defensive systems can play an essential role in reducing reliance on threats of massive destruction that are increasingly hollow and morally unacceptable. A strategy that places increased reliance on defensive systems can offer a new basis for managing our long-term relationship with the Soviet Union. It can open new opportunities for pursuing a prudent defense of Western security through both unilateral measures and agreements. The Soviets have often used arms negotiations to pursue competitive military advantage. The Soviet Union is likely to cooperate in pursuing agreements that are mutually beneficial *only* if it concludes that it cannot accomplish its present political goals because it faces Western firmness and ability to resist coercion.

- Technologies for ballistic missile defenses, together with those for precise, effective, and discriminate nuclear and nonnuclear offensive systems, are advancing rapidly. They can present opportunities for resisting aggression and deterring conflict that are safer and more humane than exclusive reliance on the threat of nuclear retaliation.

- A satisfactory deterrent requires a combination of more discriminating and effective offensive systems to respond to enemy attacks plus defensive systems to deny the achievement of enemy attack objectives. Such a deterrent can counter the erosion of confidence in our alliance guarantees caused by the adverse shifts in the military balance since the 1960s.

- Readiness to deploy advanced ballistic missile defense systems is a necessary part of a U.S. hedge against the increasingly ominous possibility of one-sided Soviet deployment of such systems. Such a Soviet deployment, superimposed on the present nuclear balance, would have disastrous consequences for U.S. and allied security. Clearly this possibility, especially in the near term, also requires precautionary measures to enhance the ability of our offensive forces to penetrate defenses.

The Preferred Path to the President's Goal: Intermediate Options

2. *The new technologies offer the possibility of a multilayered defense system able to intercept offensive missiles in each phase of their trajectories.* In the long term, such systems might provide a nearly leakproof defense against large ballistic missile attacks. However, their components vary substantially in technical risk, development lead time, and cost, and in the policy issues they raise. Consequently, partial systems, or systems with more modest technical goals, may be feasible earlier than the full system.

3. *Such "intermediate" systems may offer useful capabilities.* The assessment in this study of the utility of intermediate systems is necessarily tentative, owing to the current lack of specificity in systems design, effectiveness and costs. Nevertheless, it indicates that, given a reasonable degree of success in our R&D efforts, intermediate systems can strengthen deterrence. They will greatly complicate Soviet attack plans and reduce Soviet confidence in a successful outcome at various levels of conflict and attack sizes, both nuclear *and nonnuclear.* Even U.S. defenses of limited capability can deny Soviet planners confidence in their ability to destroy a sufficient set of military targets to satisfy enemy attack objectives, thereby strengthening deterrence. Intermediate defenses can also reduce damage if conflict occurs. The combined effects of these intermediate capabilities could help to reassure our allies about the credibility of our guarantees.

4. *A flexible research and development (R&D) program designed to offer early options for the deployment of intermediate systems, while proceeding toward the President's ultimate goal, is preferable to one that defers the availability of components having a shorter development lead time* in order to optimize the allocation of R&D resources for development of the "full system."

- Intermediate defense systems can help to ameliorate our security problems in the interim while full systems are being developed.

- The full-system approach involves higher technical risk and higher cost. On the other hand, an approach explicitly addressing the utility of intermediate systems offers a hedge against the possibility that nearly leakproof defenses may take a very long time, or may prove to be unattainable in a practical sense against a Soviet effort to counter the defense.

- The deployment of intermediate systems would also provide operational experience with some components of later, more comprehensive, and more advanced defense systems, increasing the effectiveness of the development effort.

5. We have considered several possible intermediate options:

- *Anti-Tactical Missile (ATM) Options*

  Deployment of an anti-tactical missile (ATM) system is an intermediate option that might be available relatively early. The system might combine some advanced midcourse and terminal components identified by the Defensive Technologies Study with

a terminal underlay. The advanced components, though developed initially in an ATM mode, might later play a role in continental United States (CONUS) defense. Such an option addresses the pressing military need to protect allied forces as well as our own, in theaters of operations, from either nonnuclear or nuclear attack. It would directly benefit our allies as well as ourselves. Inclusion of such an option in our long-range R&D program on ballistic missile defenses should reduce allied anxieties that our increased emphasis on defenses might indicate a weakening in our commitment to the defense of Europe. We can pursue such a program option *within ABM Treaty constraints*. Such a course is therefore consistent with a policy of deferring decisions on modifying or withdrawing from the treaty.

- *Intermediate CONUS Options*

  Intermediate capabilities may also have important applications in CONUS, initially to defend critical installations such as C^3I nodes. As the defense system is thickened, it also will add to Soviet uncertainties in targeting, even in large-scale attacks, thereby enhancing deterrence. Depending on rates of progress in the R&D program, a two-phase defense of high effectiveness against moderate threats might comprise both endoatmospheric and exoatmospheric components employing space-based sensors and ground-based interceptors. These intermediate components would be the lower tiers in a full multilayered system.

- *Limited Boost-Phase Intercept Options*

  Some intermediate options may provide useful near-term leverage on Soviet plans and programs even if they prove unable to meet fully sophisticated Soviet responses. An early boost-phase intercept system with capability against large rockets similar to those that are an important part of Soviet forces may be one example. Such an option could impose costs on the Soviets and increase their incentive to move toward an offensive posture that is more stable and less threatening. A definitive assessment of the utility of such options must specify their technological and political feasibility, timing, and cost, and the ease with which they can be countered.

6. Pursuit of the President's goal, especially if it is interpreted solely in terms of the full, nearly leakproof system, will raise questions about our readiness to defend against other threats, notably that of air attack by possible advanced bombers and cruise missiles. An appropriate response to such questions will require an early and comprehensive review of air defense technologies, leading to the development of useful systems concepts.

Defensive Systems and Stability of Deterrence

7. Deployment of defensive systems can increase stability, but to attain this goal we must design our offensive and defensive forces properly; especially, we must not allow them to be vulnerable. In combination with other measures, defenses can contribute to reducing the prelaunch vulnerability of our offensive forces. To increase stability, defenses must themselves avoid high vulnerability, must be robust in the face of enemy technical or tactical countermeasures, and must compete favorably in cost with expansion of the Soviet offensive force.

8. As currently assessed, some boost-phase intercept systems and other space-based components pose serious policy problems, because of engagement time constraints. Space-based components may also be highly vulnerable to Soviet boost-phase intercept systems, or anti-satellite (ASAT) systems. It will be imperative to design systems which are not themselves subject to rapid attack. Alternative approaches need to be developed in the R&D program that permit safe arrangements for the operation of the defensive system.

Soviet Policies, Initiative, and Responses

9. *The common assumption that the decision to initiate widespread deployment of ballistic missile defense systems rests with the United States alone is completely unjustified.* Soviet history, doctrine, and programs all indicate that the Soviets are likely (and better prepared than we) to initiate a widespread antiballistic missile (ABM) deployment whenever they deem it to their advantage.

10. The long-term course of Soviet military policy plans and programs is uncertain in detail, but unless there is a major change in their political goals, the Soviets are highly likely to continue to aim at being able to defeat any combination of external enemies.

- The Soviets will almost certainly continue to maintain and upgrade their large air defenses and to conduct programs for R&D and modernization of their ballistic missile defenses. These activities will increasingly create uncertainty about the ability of U.S. missile forces to penetrate without countermeasures, and about the possibility of a sudden (open) or gradual (clandestine) Soviet breakout from the ABM Treaty constraints. The importance of such uncertainty is intensified because of the substantial Soviet investments in air defense and passive defenses of elements of the Soviet military and government. Even without violating ABM Treaty constraints, the Soviets will probably deploy a substantial ATM defense, exacerbating our problems in theaters of operations and making them more difficult to correct.

- On the other hand, if the Soviets believe that a Western deployment of defenses will substantially improve the West's capability to resist attack or coercion, they will try to prevent a Western deployment through political means or arms negotiations.

- If the United States deploys defensive systems, the Soviets will probably seek to maintain their offensive threat through a set of measures that will depend on their assessment of the defenses and their own technological options. Depending on the defense effectiveness and leverage, such a response may not fully restore Soviet offensive capabilities.

- If, over time, the Soviets become convinced that the West has the resolve and ability to block Soviet achievement of their long-term goals of destabilization and domination of other states, they may move from their present political/military policies to become more willing to agree to reducing the nuclear threat, through a combination of mutual restrictions on offensive forces and deployment of defensive systems.

B. SUPPORTING RATIONALE

President Reagan's directive to assess the role of defensive systems has required the FSSS to consider the relation of these systems to our strategic objectives and to Soviet programs and policy. The role of intermediate defensive systems has been a major focus of our study.

1. *The Need for Defensive Systems in our Security Strategy*

There is a broad consensus that reliance on nuclear retaliatory threats raises serious political and moral problems, particularly in contingencies where the enemy use of force has been constrained. Technologies for defensive systems and those for extremely precise and discriminating attacks on strategic targets have been advancing very rapidly. (Many technologies are common to both functions.) Together they offer substantial promise of a basis for protecting our national security interests, and those of our allies, that is more humane and more prudent than sole reliance on threats of nuclear response. The case for increasing the emphasis on defensive programs in our national security strategy rests on several grounds, in addition to the broad, long-term objectives mentioned by the President in his March 23 speech:

- The massive increase in Soviet power at all levels of conflict is eroding confidence in the threat of U.S. nuclear response to Soviet attacks against our allies. A continuation of this erosion could ultimately undermine our traditional alliance structure.

- If the Soviet Union persists in the buildup of nuclear offensive forces, for the next decade and beyond the United States may not wish to restore, by offensive means alone, a military balance consistent with our strategic needs. Soviet willingness and ability to match or overmatch increases in U.S. nuclear forces suggest that while additions to our forces are needed to maintain the continued viability of our nuclear deterrent, such additions alone may not preserve confidence in our alliance guarantees.

- The public in the United States and other Western countries is increasingly anxious about the danger of nuclear war and the prospects for a supposedly unending nuclear arms race. Those expressing this anxiety, however, frequently ignore the fact that

the U.S. nuclear stockpile has been declining, both in numbers and in megatons, while Soviet forces have increased massively in both. A U.S. counter to the Soviet buildup that emphasized increases in U.S. nuclear stockpiles would exacerbate public anxieties.

- Arms agreements, despite widespread Western hopes for them, have to date failed to prevent growing instability in the balance—and the deterioration—in the Western position relative to the East. Offensive force limitation agreements, originally associated in the U.S. arms control strategy with the ABM Treaty, have failed to restrain the Soviet offensive buildup; *de facto* reductions in the explosive yield and size of U.S. strategic nuclear stocks have not prevented vast increases in the size and destructiveness of the Soviet stockpile.

- Rapidly advancing technologies offer new opportunities for active defense deployment against ballistic missile attack that did not exist when, over a decade ago, the United States abandoned plans for defense deployments against nuclear attack. Technologies for sensing and discrimination of targets, directing the means of intercept, and destroying targets have created the possibility of a system of layered defenses that would pose successive, independent barriers to penetrating missiles. There has been improvement in some (not all) aspects of defense vulnerability. Given successful outcomes to development programs and robustness in the face of Soviet countermeasures, such defenses would permit only a very small proportion of even a very large attacking ballistic missile force to reach target. Such defenses might also offer high leverage in competing with offensive responses.

2. *Ballistic Missile Defenses in the Soviet Union*

The Soviets maintain a high level of activity in programs relevant to defenses against nuclear attack including:

- Active programs for modernizing deployed air and ballistic missile defense systems which together give them the basis for a very rapid deployment of widespread ballistic missile defenses, if they decide to ignore ABM Treaty obligations completely and openly.

- Large and diverse R&D programs in areas of technology for advanced ballistic missile and air defense systems.

- A space launch capacity significantly greater than our own, if not as sophisticated.

A substantial Soviet lead in deployed defensive systems, superimposed on their growing offensive threat against our nuclear offensive forces, could destroy the stability of the strategic balance.

The decision to initiate widespread deployment of ballistic missile defenses does not rest with the United States alone. The common assumption that it does is completely unjustified. The Soviets give every appearance of preparing for such a deployment whenever they believe

they will derive significant strategic advantage from doing so. Their activities include some that are questionable under the ABM Treaty. Unless the public is aware and kept aware of Soviet activities in this area, the United States will probably be blamed for initiating "another round in the arms race." The state of U.S. preparedness to deploy capable defenses will be an important element in the Soviets' assessment of their own options. Active U.S. R&D programs on advanced defensive systems can assist in deterring a Soviet deployment designed to exploit an asymmetry in their favor.

3. *Alternative Paths to the President's Objective*

The path to the President's ultimate objective may be designed to go directly toward the ultimate objective of a full, multilayered system that offers nearly leakproof defenses against very large offensive forces. Under some conditions such a path might be an optimal use of limited R&D resources, concentrating first on those technologies that present the greatest difficulty and require the greatest lead times.

Alternatively, R&D programs might be designed to provide earlier options for the deployment of intermediate systems, based on technologies that can contribute to the ultimate objective, as such systems become technically feasible and offer useful capabilities. Such a path toward the President's ultimate goal might generate earlier funding demands to support deployment of intermediate systems and would require early treatment of some of the policy issues. Also, at least one variant considered in our report, an ATM deployment for theaters of operations, could be undertaken without modification of the ABM Treaty.

The principal benefits of an R&D path providing options for earlier, partial deployments are:

- Possibilities for an early contribution to improving the deteriorating military balance.
- Its explicit provision of a hedge against the risks inherent in a program where each of a large number of demanding technological goals must be met in order to realize any useful result at all.
- The likelihood that early deployments of parts of the ultimate system may also prove to be the most effective path to achieving such a system; early operational experience with some system elements can contribute useful feedback to the development process.

4. *Intermediate Defensive Systems, Soviet Strategy, and Deterrence*

Fundamentally, the choice between the two paths depends on the utility of intermediate systems in meeting our national security objectives. In the discussion of ballistic missile defenses that preceded the U.S. proposal of the ABM Treaty, opponents of such defenses argued that the utility of widespread defense deployments should be judged in terms of their ability to protect population from large attacks aimed primarily at urban-industrial areas. Because of the destructiveness of nuclear weapons, nearly leakprook defenses are required to provide a high level of protection for population against such attacks. Moreover, opponents at that time also divided our strategic objectives into two categories: deterrence of war and limiting

damage if deterrence failed. They relegated defenses exclusively to the second objective and ignored the essential complementarity between the two objectives. Consequently, they assigned defenses no role in deterrence.

We have reexamined this issue, and we conclude that defenses of intermediate levels of capability can make critically important contributions to our national security objectives. *In particular, they can reinforce or help maintain deterrence by denying the Soviets confidence in their ability to achieve the strategic objectives of their contemplated attacks as they assess a decision to go to war.* By strengthening deterrence *at various levels of conflict,* defenses can also contribute valuable reassurance to our allies.

Deterrence rests on the Soviets' assessment of their political/military alternatives. This, in turn, depends on their objectives and style in planning for and using military force. It also depends on their estimates of the effectiveness of weapons and forces on both sides. Soviet assessments on these matters may differ sharply from our own. Specifically, the past behavior of the Soviets suggests they credit defensive systems with greater capability than we do. If true, this will increase the contribution of defensive systems to deterrence.

Because of the long lead times, assessment of the strategic role of defenses also requires very long-term projections about the nature of the Soviet state. While such projections cannot be made with confidence, there is no current basis for projecting a fundamental change in the Soviet attitude toward external relations. We consider below the possibility that appropriate management by the West of its long-term relations with the Soviets might induce a fundamental change. Desirable as this goal is, the most probable projection for the foreseeable future is that they will continue to set a high priority on their ability to control, subvert, or coerce other states as the basis for their foreign relations. In this case, military power will continue to play a major role for the Soviets, and many present elements of style in the application of that power can be expected to persist:

- Domination of the Eurasian periphery is a primary strategic objective. The Soviets' preferred mode in exploiting their military power is to apply it to deter, influence, coerce—in short, to control—other states, if possible without combat. But the ability to so apply this power depends on strength in actual combat.

- The Soviet objective in combat is victory, defined as survival of the Soviet state and military power (with as little damage as possible) and the imposition of the Soviet will on opponents. Soviet doctrine and practice contemplate limited war, viewed in terms of Soviet ability to impose limitations on opponents for Soviet strategic advantage.

- Soviet plans unite the roles of various elements of military forces in a coherent strategic architecture, embracing offense, defense, and combined arms in various theaters of operations. Destruction of an enemy is subordinate to the achievement of the goal of victory. The Soviets' concept for use of strategic offensive and defensive capability is, consequently, to deter attacks by U.S. intercontinental forces, to separate the United States from its allies in the Eurasian periphery, and to limit damage in the event that U.S. offensive forces are used against the Soviet Union.

- Uncertainty is a dominant factor in all combat, creating an unlimited demand for superiority in forces. Soviet planners seek ways to control uncertainty but, faced with uncertainty over which they cannot exercise a high degree of control, Soviet military action may be deterred. Uncertainties are particularly important in technically complex interactions between offense and defense.

Such a view of military force and its political applications may appear inconsistent with Soviet threats of inevitable apocalyptic destruction in the event of war at any level—but such threats are intended to play on the fears of the Western public. While very great destruction might in fact result from Soviet attacks, the discussion above suggests that the Soviets give priority to military targets. In the absence of defenses, their massive offensive forces make it possible for them to attack large numbers of targets, including urban-industrial targets as well as high-priority military targets.

Whether they would conduct such attacks from the outset or withhold attacks against urban-industrial targets to deter U.S. retaliation must be a matter of conjecture. In any case, intermediate levels of defense capability might deny them the ability to destroy with high confidence all of their high-priority targets and force them to concentrate their attack on such targets, diverting weapons that might otherwise be directed against cities. Moreover, if defenses can deny the Soviets confidence in achievement of their military attack objectives, this will strengthen deterrence of such attacks. Thus, to the extent that such attacks are necessary to overall Soviet plans, defenses can help deter lower levels of conflict.

5. The Military Utility of Intermediate Defensive Systems

Defensive systems affect attack planning in a variety of ways, depending on the characteristics and effectiveness of the defenses, the objectives of the attack, and the responses of the defense and offense to the measures adopted by the other side.

Any defense system can be overcome by an attack large enough to exhaust the intercept capability of the defense. The size of attack against which the defense is designed is therefore one major characteristic of a defensive system. The cost of expanding the defense to deal with a given increase in the size and cost of the offense is a measure of the leverage of the defense. Another characteristic is its effectiveness—its probability of destroying an offensive missile.

If the defense has sufficiently high capacity, effectiveness, and leverage, it can of course essentially preclude attacks. Such defenses may result from the R&D programs pursuant to the President's goal, but it is more likely that the results will be more modest. Even a modest level of effectiveness—for example, a kill probability of 0.5 for each layer of a four-layer defense—yields an overall "leakage" rate of only about 6 percent for an attack size that does not exceed the total intercept capacity of the various layers. Such a leakage rate is, of course, sufficient to create catastrophic damage in an attack of, say, 5,000 reentry vehicles (RVs) aimed at cities. It would mean 300 RVs arriving at targets—sufficient to destroy a very large part of our urban structure and population even if distributed in a nonoptimal fashion from the point of view of the offense.

Against an extensive military target system, however, with an attack objective of destroying large fractions of specific target sets (such as critical C^3I facilities) with high confidence,

such a leakage rate would be totally inadequate for the offense. The more specific the attack objectives and the higher the confidence required by the offense, the greater the leverage exacted by the defense. For example, in the previous four-layer case, if the defense required a high-confidence penetration against a specific target, it would need to fire at least 30 RVs to a single target since the defense firing doctrine is unknown to the attacker. As these are expected-value calculations, an attacker would have to double or triple the above values to attain high confidence in killing a specific target. Clearly an attacking force of 5,000 RVs that could destroy a very large military target system in the absence of defenses would be totally inadequate to achieve high confidence of destruction of a large fraction of a defended target set amounting to hundreds of targets. Yet, this is precisely what is required to achieve the strategic objectives of a large-scale nuclear attack.

The situation is even more dramatic in the case of limited attacks on restricted target systems, intended to achieve a decisive strategic advantage while continuing to deter further escalation of the level of nuclear attack. Such attacks would be precluded entirely by defenses of the sort discussed, would deny the attacker's confidence in the outcome, or would require a level of force inconsistent with limiting the level of violence, while depleting the attacker's inventory available for other tasks.

Offense and defense have a rich menu of responses from which they can choose. These include fractionation of payload to increase the number of warheads for a given missile force, the use of decoys, and the use of preferential offense or defense tactics. The outcome of the contest is likely to be uncertain to both sides so long as the defense keeps pace with additions to offensive force size by expanding its intercept capacity and upgrading its critical subsystems. Uncertainty about the offense-defense engagement itself contributes to deterrence of attack by denying confidence in the attack outcome.

We have considered the effect of introducing defenses in hypothetical representative military situations, taking account of what we know of Soviet objectives and operational style in combat. In their doctrine, the Soviets stress operations designed to bring large-scale conflict to a quick and decisive end, at as low a level of violence as is consistent with achievement of Soviet strategic aims. To achieve this objective in a conflict involving NATO, a major aspect of their operations is intense initial attacks on critical NATO military targets in the rear, particularly those relevant to NATO's theater nuclear capabilities and air power. Such attacks (including those in the nonnuclear phase of combat) are intended to contribute to Soviet goals at that level, to reduce NATO's ability and resolve to initiate nuclear attacks if the nonnuclear defense fails to hold, and to assist in nuclear preemption of a NATO nuclear attack. High confidence in degrading NATO air power is also essential to support utilization of Soviet operational maneuver groups designed to disrupt NATO rear areas.

The Soviets plan to use a wide variety of means to accomplish this task. Tactical ballistic missiles (TBMs) are taking an increasing role in this mission during the initial stages of either nuclear or nonnuclear combat as their accuracy increases and the sophistication of high-explosive warheads increases. Inability to destroy critical target systems would cast doubt on the feasibility of the entire Soviet attack plan, and so contribute to deterrence of theater combat, nuclear or nonnuclear.

In the event of imminent or actual large-scale conflict in Europe, another high-priority Soviet task would be to prevent quick reinforcement and resupply from the United States.

Early and obvious success in this respect, by demonstrating the hopelessness of resistance, might abort European resistance altogether or end a conflict in its very early stages. In the absence of defenses, the Soviets might attempt this task by nonnuclear tactical ballistic missile attacks on reception facilities in Europe. The Soviets could also accomplish this task with higher confidence by means of quite limited nuclear attacks on such facilities in Europe and on a restricted set of force projection targets in CONUS.

While the risk of provoking large-scale U.S. response to nuclear attacks on CONUS might be unacceptable to the Soviets, they might also feel that—given the stakes, the risks of escalation if conflict in Europe is prolonged, and the strength of their deterrent to U.S. initiation of a large-scale nuclear exchange—the *relative* risks might be acceptable if the attack size were small enough and their confidence of success sufficiently high. Without defenses, very small numbers of ballistic missiles could in fact achieve high confidence in such an attack. However, an intermediate ballistic missile defense deployment of moderate capabilities could force the Soviets to increase their attack size radically. This would reduce or eliminate the Soviets' confidence that they could achieve their attack objectives while controlling the risks of a large-scale nuclear exchange. The role of intermediate defenses in large-scale nuclear attacks has already been discussed at the beginning of this section.

Soviet response to prospective or actual defense deployments by the United States also will have longer-run aspects. The Soviets' initial reaction will be to assess the nature, effects, and likelihood of a U.S. defense deployment. Barring fundamental changes in their conception of their relations to other states and their security needs, they will seek to prevent such a deployment through manipulation of public opinion or negotiations over arms agreements. (We consider the possibility of a fundamental change in Soviet political/military objectives in the discussion of arms agreements below.)

If the Soviets fail to prevent the deployment of defenses, they will assess their alternative responses in the light of the strategic architecture discussed above, the effectiveness and leverage of the U.S. ballistic missile defenses, and other relevant U.S. offensive and defensive capabilities (e.g., air defense). If the new defensive technologies offer sufficient leverage against the offense and they cannot prevent the West from deploying defensive systems, the Soviets may accept a reduction in their long-range offensive threat against the West, which might be reflected in arms agreements. In this case, they would probably seek to compensate by increasing their relative strength in other areas of military capability. Their current program emphases suggest that they would be more likely to respond with a continuing buildup in their long-range offensive forces. However, such a buildup would not necessarily be sufficient to maintain their current level of confidence in the achievement of the strategic objectives of those forces.

6. *Managing the Long-Term Competition with the Soviet Union*

Current Soviet policy on arms agreements is dominated by the Soviet Union's attempt to derive unilateral advantage from arms negotiations and agreements, by accepting only arrangements that permit continued Soviet increases in military strength while using the negotiation process to inhibit Western increases in military strength. There is no evidence that Soviet emphasis on competitive advantage over mutual benefit will change in the near future, unless a fundamental change occurs in the Soviet Union's underlying foreign policy objectives. Such

a change might be induced in the long run by a conviction among Soviet leaders that the West was able and resolved to block the Soviet Union's attempts to extend its power and influence by reliance on military strength. If such a change occurred, the possibilities for reaching much more substantial arms agreements might increase. In that event, it might also be possible to reach agreements restricting offensive forces so as to permit defensive systems to diminish the nuclear threat. Soviet belief in the seriousness of U.S. resolve to deploy such defenses might itself contribute to such a change.

7. *Defenses and Stability*

Deployment of defensive systems can increase stability, but to attain this we must design our offensive and defensive forces properly—and, especially, we must not allow them to be vulnerable. In combination with other measures, defenses can contribute to reducing the prelaunch vulnerability of our offensive forces. To increase stability, defenses must themselves avoid high vulnerability, must be robust in the face of enemy technical or tactical countermeasures, and must compete favorably in cost terms with expansion of the Soviet offensive force. A defense that was highly effective for an attack below some threshold but lost effectiveness very rapidly for larger attacks might decrease stability if superimposed on vulnerable offensive systems. Boost-phase and midcourse layers may present problems of both vulnerability and high sensitivity to attack size. Nevertheless, if this vulnerability can be limited through technical and tactical measures, these layers may constitute very useful elements of properly designed multilayered systems where their sensitivity is compensated by the capabilities of other system components.

8. *A Perspective on Costs*

We do not yet have a basis for estimating the full cost of the necessary research program nor the cost of systems development or various possible defensive deployment options. It is clear, however, that costs and the tradeoffs they require would present important issues for defense policy. While not insignificant, total systems costs would be spread over many years. There is no reason at present to assume that the potential contributions of defensive systems to our security would not prove sufficient to warrant the costs of deploying the systems when we are in a better situation to assess their costs and benefits.

THE STRATEGIC DEFENSE INITIATIVE

Defensive Technologies Study



MARCH 1984

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THE UNDER SECRETARY OF DEFENSE

WASHINGTON, D.C. 20301

RESEARCH AND
ENGINEERING

On March 23, 1983, President Reagan challenged the scientific community of the United States to investigate whether new technologies could provide the means for countering the awesome threat of nuclear ballistic missiles.

Following his historic speech, the President directed an intensive study to define the technologies necessary for defending the United States and our allies from ballistic missile attack. We collected over 50 of our nation's top scientists and engineers and asked them to assess the feasibility of achieving this goal and to structure a research program to develop the technologies that could provide an effective defense against ballistic missiles. This report summarizes the results of their effort, the Defensive Technologies Study.

The principal finding of the Defensive Technologies Study Team was that, despite the uncertainties, new technologies hold great promise for achieving the President's goal of eliminating the threat of ballistic missiles to ourselves and our allies. Based on the technical recommendations of this study the United States has structured a focused research and technology program of the highest priority to pursue these new technologies. This Strategic Defense Initiative will provide future Presidents with an option to enhance our deterrence capability by basing it on a mix of offensive and defensive forces. The Strategic Defense Initiative will have three aspects as its hallmark: innovation, focused technology programs, and technical demonstration milestones.

Our scientists and engineers are aware, like the President, that we face significant technical challenges and uncertainties. Yet, as we move into the next decade, I am confident that our greatest asset, our people's ingenuity and creativity, will make the President's vision a reality. We will pursue the Strategic Defense Initiative with utmost vigor. I believe that within the technologies reviewed by the Defensive Technologies Study are the seeds of a safer world. We owe it to ourselves, our allies, and most of all to our children to meet the President's challenge.

R. D. DeLauer

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In March 1983 President Reagan established as a long-term national goal an end to the threat of ballistic missiles. He said that "we must thoroughly examine every opportunity for reducing tensions and for introducing stability into the strategic calculus on both sides." He asked the scientific community to give the United States "the means of rendering" the ballistic missile threat "impotent and obsolete."

Shortly after his address to the Nation, the President directed that an intensive analysis be conducted, to include a Defensive Technologies Study to identify the most promising approaches to effective defense against ballistic missiles and to describe a technically feasible research and development program. A study team was formed and worked under the leadership of Dr. James C. Fletcher. This paper summarizes the team's report.

SUMMARY AND CONCLUSIONS OF THE DEFENSIVE TECHNOLOGIES STUDY

The Defensive Technologies Study analyzed the technological feasibility of developing an effective defense against ballistic missiles and proposed programs in the areas of (1) surveillance, acquisition, and tracking; (2) directed energy weapons; (3) conventional weapons; (4) battle management, communications, and data processing; (5) systems concepts; and (6) countermeasures and tactics. Classified reports for each area and a Summary, Defense Technology Plan have been issued. Presented here is an unclassified overview of the summary report, with its principal findings.

The Study Team identified a long-term, technically feasible research and development plan. The goal of the study was to provide the basis for selecting the technology paths to follow when a specific defensive strategy is chosen. At the same time, near-term demonstrations of some system components were

identified that could provide options for early deployment and meaningful levels of effectiveness against constrained threats. The plan also incorporates ideas for enhancing the defense of NATO and other allies.

The study reviewed, evaluated, and placed priorities on the technological issues underlying the ballistic missile defense of the United States and its allies. Also reviewed was a set of strategic defense system concepts and supporting technologies in various states of development. In addition, the study considered system concepts where technological attributes were not preeminent, for example, concepts constrained by fiscal considerations. The study did not consider defenses against threats other than ballistic missiles, such as bombers and cruise missiles or conventional forces; these issues are dealt with in other Department of Defense studies.

The Defensive Technologies Study Team identified a research and development program to allow knowledgeable decisions on whether, several years from now, to begin an engineering validation phase that, in turn, could lead to an effective defensive capability in the 21st century. Similarly, intermediate deployments could be feasible that would provide meaningful levels of defense, especially against constrained threats.

The Defensive Technologies Study concluded that

- Powerful new technologies are becoming available that justify a major technology development effort offering future technical options to implement a defensive strategy

- Focused development of technologies for a comprehensive ballistic missile defense will require strong central management

- The most effective systems have multiple layers, or tiers

- Survivability of the system components is a critical issue whose resolution requires a combination of technologies and tactics that remain to be worked out

- Significant demonstrations of developing technologies for critical ballistic missile defense functions can be performed over the next 10 years that will provide visible evidence of progress in developing the technical capabilities required of an effective in-depth defense system.

ADVANCES IN DEFENSIVE TECHNOLOGIES

The ballistic missile threat has increased significantly over the past 20 years, so an appropriate question is: "What has happened to justify another evaluation of ballistic missile defense as a basis for a major change in strategy?" Advances in defensive technologies warrant such a reevaluation.

Two decades ago there were no reliable approaches to the problem of boost-phase intercept; however, multiple approaches now exist based on directed energy concepts such as particle beams and lasers and kinetic-energy target destruction mechanisms.

Intercept in midcourse was difficult 20 years ago because of no credible concepts for decoy discrimination, the intercept cost, and the collateral effects of nuclear weapons used for the interceptor warheads. Today, multispectral sensing of discriminants with laser imaging and millimeter-wave radar, birth-to-death tracking, and direct-impact projectiles that

have promise as inexpensive interceptors appear to eliminate the difficulties of midcourse intercept.

In the 1960s an inability to discriminate penetration aids at high altitudes and limited interceptor performance resulted in very small defended areas for each terminal site and required an unacceptably high number of interceptors for effective defense. Now, technological advances may offer ways to discriminate among incoming objects and to allow intercepts at high altitudes. When these improvements are coupled with the potential for boost-phase and midcourse intercepts to disrupt pattern attacks, the effectiveness of terminal defenses is significantly increased.

Likewise, 1960s technology in computer hardware and software and signal processing was incapable of supporting battle management of the multitiered defense. Because of technological advances, the needed command, control, and communications facilities in all likelihood will be realized.

Several new technologies and concepts emerged from the work of the Defensive Technologies Study Team that, considered with those already well known, illustrate how far defensive technology has progressed over the past two decades. For example, throughout the phases of a ballistic missile trajectory, there are many observables, and by using both active and passive sensors, a selection of them can be measured. That is, it is likely that discrimination can be done between a warhead and a decoy or debris as threat objects proceed toward their targets. An active sensor works on the same principle as radar; a passive sensor relies on radiation emanating from the target. Some possible technologies the study identified for surveillance, acquisition, and tracking were active techniques such as thermal response of a target to a continuous-wave laser and passive

techniques such as imaging with infrared sensors. Although any one sensor can be defeated, it is very difficult to defeat several operating simultaneously.

The study also identified several concepts for the intercept and destruction of targets. Kinetic energy, or impact, devices include exoatmospheric and high endoatmospheric, nonnuclear, rocket-propelled projectiles and hypervelocity guns. Directed energy concepts with significant potential include ground- or space-based particle beams, Also identified were potential concepts for enhanced battle management and command, control, and communications as well as several different ways to ensure space systems survivability.

THE THREAT

A variety of potential threats were considered, ranging from an attack with fewer than 100 ballistic missiles and a few hundred warheads to a simultaneous launch attack with more than 3,000 missiles and over 30,000 warheads. The Study Team selected a defense-in-depth approach because of the stress imposed by a maximum, unconstrained ballistic missile offense. The critical technologies highlighted later are best understood in the context of this threat.

PROGRAM MANAGEMENT

The study concluded that a high priority should be placed on central management of the research and development program and there should be streamlined budgeting and contracting and effective security.

THE BALLISTIC MISSILE DEFENSE ENVIRONMENT

The four phases of a typical ballistic missile trajectory are shown in Figure 1. First, there is a boost phase when the

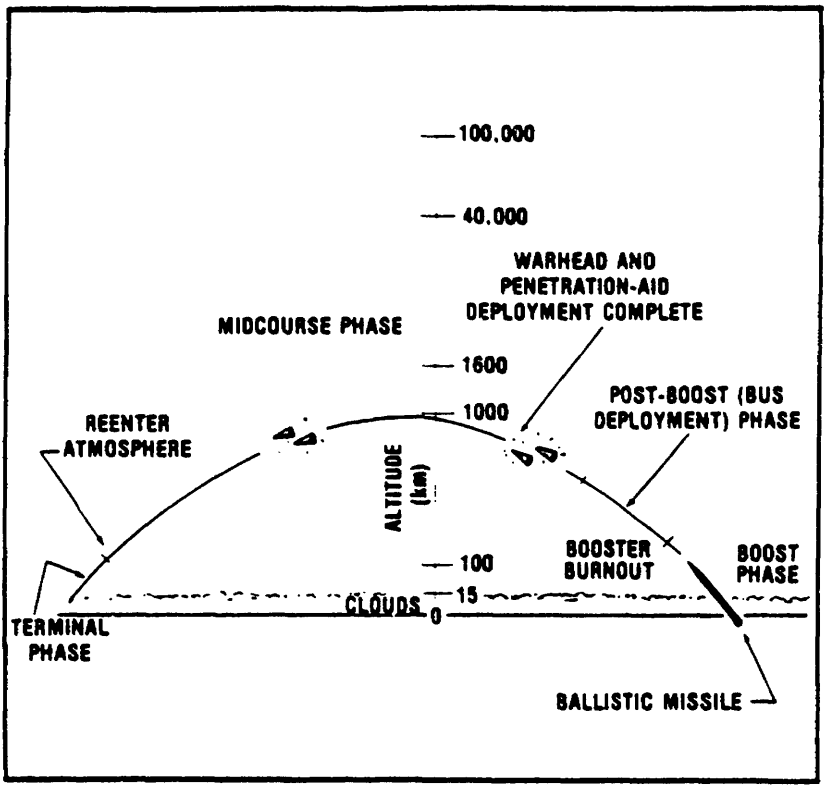


Figure 1: The phases of a typical ballistic missile trajectory. During the boost phase the rocket engines accelerate the missile payload through and out of the atmosphere and provide intense, highly specific observables. A post-boost, or bus deployment, phase occurs next, during which multiple warheads and penetration aids are released from a post-boost vehicle. In the midcourse phase the warheads and penetration aids travel on trajectories above the atmosphere, and they reenter it in terminal phase, where they are affected by atmospheric drag.

first- and second-stage engines are burning and offering intense, highly specific observables. A post-boost, or bus deployment, phase occurs next, during which multiple warheads and penetration aids are released from a post-boost vehicle. Then, there is a midcourse phase when warheads and penetration aids travel on ballistic trajectories above the atmosphere. Finally, there is a terminal phase in which the warheads and penetration aids reenter the atmosphere and are affected by atmospheric drag.

A ballistic missile defense capable of engaging the target all along its flight path must perform certain key functions:

- Rapid and reliable warning of an attack and initiation of the engagement. This requires global, full-time surveillance of ballistic missile launch areas to detect an attack and define its destination and intensity, to determine likely targeted areas, and to provide data for handoff to boost-phase intercept and post-boost vehicle tracking systems.

- Efficient intercept and destruction of the booster and post-boost vehicle. The defense must be capable of dealing with attacks ranging from a few tens of missiles to a massive, simultaneous launch. In attacking post-boost vehicles, the defense prefers to attack as early as possible to minimize the number of penetration aids deployed.

- Efficient discrimination through bulk filtering of lightweight penetration aids. The price to the offense in mass, volume, and investment for credible decoys should be high.

- Enduring birth-to-death tracking of all threatening objects. This enables unambiguous handover, with few errors, of reentry vehicles to designated interceptors.

- Low-cost target intercept and destruction in midcourse. There should be recognition of the assigned target in the midst of a large array of penetration aids and debris. The cost to the defense for interceptors should be less than the cost to the offense for warheads.

- High endoatmospheric terminal intercept and destruction. This involves relatively short-range intercept of each reentering warhead.

- Battle management, communications, and data processing. These elements coordinate the system components for effectiveness and economy of force.

It is generally accepted, on the basis of many years of ballistic missile defense studies and associated experiments, that an efficient defense against a high-level threat would be a multitiered defense-in-depth requiring all the capabilities listed above. For each tier there will be leakage, that is, threat objects that have not been intercepted and hence move on to the next phase. For example, three tiers, each of which allows 10 percent leakage, yielding an overall leakage of 0.1 percent, are likely to be less costly than a single layer that is 99.9 percent effective. In addition, a multitiered defense is the optimum counter to structured attacks: any given offense response affects only one phase.

The defended area of a terminal-defense interceptor is determined, working backward in a ballistic missile trajectory,

by how fast the interceptor can fly and how early it can be launched. Terminal-defense interceptors fly within the atmosphere, and their velocity is limited. How early they can be launched depends on the requirements for discrimination of the target from penetration aids and accompanying debris. Because the terminal defense of a large area requires many interceptor launch sites, the defense is vulnerable to saturation tactics.

It is desirable, therefore, to complement the terminal defense with area defenses that intercept at long ranges. Such a complement is found in a system for exoatmospheric intercepts in the midcourse phase.

Intercept outside the atmosphere requires the defense to cope with decoys designed to attract interceptors and exhaust the defending force prematurely. Fortunately, available engagement times in midcourse are longer than in other phases. The midcourse defensive system must provide both early filtering, or discrimination, of nonthreat objects and continuing attrition of threat objects if the defense is to minimize the pressure on the terminal system. Intercept before midcourse is attractive because starting the defense at midcourse accepts the potential of a large increase in targets from multiple independently targeted reentry vehicle and decoy deployment.

The ability to respond effectively to an unconstrained threat is strongly dependent on the viability of a boost-phase intercept system. For every booster destroyed, the number of objects to be identified and sorted out by the remaining elements of a layered ballistic missile defense system is reduced significantly. Because each future booster could be capable of deploying tens of reentry vehicles and hundreds of decoys, the leverage, or the advantage gained by the defense,

may be 100 to 1 or more. A boost-phase system is itself constrained by the relatively short engagement times and the potentially large number of targets. Because of these constraints, an efficient surveillance and battle-management system is needed.

That phase of flight in which post-boost vehicle operations occur is a transition from boost phase to midcourse. In this phase the leverage gained by the defense decreases with time as decoys and reentry vehicles are deployed. On the other hand, the post-boost phase offers additional time for intercept by boost-phase weapons, and above all an opportunity to discriminate between warheads and deception objects as they are deployed.

The phenomenology and required technology for each of these phases of a ballistic missile trajectory are quite different. In each phase of a ballistic missile flight, a defensive system must perform the basic functions of (1) surveillance, acquisition, and tracking and (2) intercept and target destruction.

SURVEILLANCE, ACQUISITION, AND TRACKING

Just as there are many tiers to the overall ballistic missile defense system, there can be more than one tier in each of the phases. These space-based surveillance, acquisition, and tracking components perform different tasks because the nature of a structured attack changes as the threat objects proceed along their trajectories. To illustrate this point and also to indicate how the components of one phase may interact with those of another phase, two potential technologies will be described -- (1) infrared sensors and laser designators for the midcourse phase and (2) infrared sensors and laser trackers for the terminal phase.

The surveillance, acquisition, and tracking function includes sensing information for battle management and processing

signals and data for discrimination of threatening reentry vehicles from other objects. As each potential reentry vehicle is released from its post-boost vehicle, it begins ballistic midcourse flight accompanied by deployment hardware and possibly by decoys. Each credible object must be accounted for in a birth-to-death track, even if the price is many decoy false alarms. Interceptor vehicles of the defense must also be tracked.

The midcourse sensors must be able to discriminate between the threatening reentry vehicles that have survived through the post-boost deployment phase and nonthreatening objects such as decoys and debris. They must also provide reentry vehicle position and trajectory data for firing interceptors and assessing target destruction. Most reentry vehicles must be recognized, even if again there are many false alarms. Requirements are to track all objects designated as reentry vehicles and other objects that may be confusing to later tiers.

Space-based, passive infrared sensors could provide a way to meet these requirements. They could permit long-range detection of cold bodies against the space background, rejection of simple lightweight objects, and birth-to-death tracking of designated objects. Laser trackers could provide imaging to determine if targets had been destroyed and precision tracking of objects as they continue through midcourse. As the objects proceed along their trajectories, data on them are handed off from sensor to sensor, and track files on threat objects are progressively improved.

The terminal phase is the final line of defense. The tasks of surveillance are to acquire and sort all objects that have leaked through early defense layers and to identify the remaining reentry vehicles. Such actions will, where possible, be based on handovers from the midcourse engagements. Objects

include reentry vehicles shot at but not destroyed, reentry vehicles never detected, and decoys and other objects that were neither discriminated nor destroyed. These credible objects must be handed off to terminal-phase interceptors.

An innovative concept for the terminal phase is the airborne optical adjunct -- a long-endurance platform that would be put into position on warning of attack -- that would detect arriving reentry vehicles using infrared sensors, as those space-based sensors had done in midcourse, tracking those that were not previously selected. The airborne sensors would also provide the data necessary for additional discrimination. They could acquire and track objects in late exoatmospheric flight and observe interactions with the atmosphere from the beginning of reentry. Then, a laser or radar would precisely measure the position of each object and refine its track just before committing the interceptors.

INTERCEPT AND TARGET DESTRUCTION

A variety of mechanisms, including directed energy, can destroy a target at any point along its trajectory. The study identified several promising ones. An excimer laser, for example, can be configured to produce a single giant pulse that delivers a resulting shock wave to a target. The shock causes structural collapse. A continuous-wave or repetitively pulsed laser delivers radiant thermal energy to the target. Contact is maintained until a hole is burned through the target or the temperature of the entire target is raised to a damaging level. Examples included in this category are free-electron lasers, chemical lasers (hydrogen fluoride or deuterium fluoride), and repetitively pulsed excimer lasers. Another way to destroy a target is with a neutral-particle beam, which deposits sufficient energy within a target to destroy its internal components. Guns and missiles destroy their targets through kinetic-energy impact. Here, homing projectiles are propelled by chemical

rockets or by hypervelocity guns, such as the electromagnetic gun based on the idea of an open solenoid.

Figures 2, 3, and 4 show ballistic missile defense during terminal, midcourse, and boost phases.

BATTLE MANAGEMENT

The purpose of battle management is to optimize the use of defense resources -- it is a data-processing and communication system that includes the command, control, and communication facilities. Its tasks are situation monitoring, resource accounting, resource allocation, and reporting.

A layered battle-management system would correspond to the different layers of the ballistic missile defense system, with each layer being semiautonomous with its own processing resources, rules of engagement, sensor inputs, and weapons. During an engagement, data would be handed over from one phase to the next. Its exact architecture would be highly dependent on the mix of sensors and weapons and the geographical scope of the defensive system that it manages.

Sensors survey the field of battle, and their raw data are filtered to reduce the volume. Later processes organize these data according to the size of the object; information specific enough to determine its orbital parameters and positions as a function of time; and a listing of other data that bear on the identity, classification, and threat status of the object being tracked. In principle, all objects in the field of view of the sensors are candidates, and all objects that cannot readily be rejected as nonthreatening will appear in the file, which is the representation of the total battle situation.

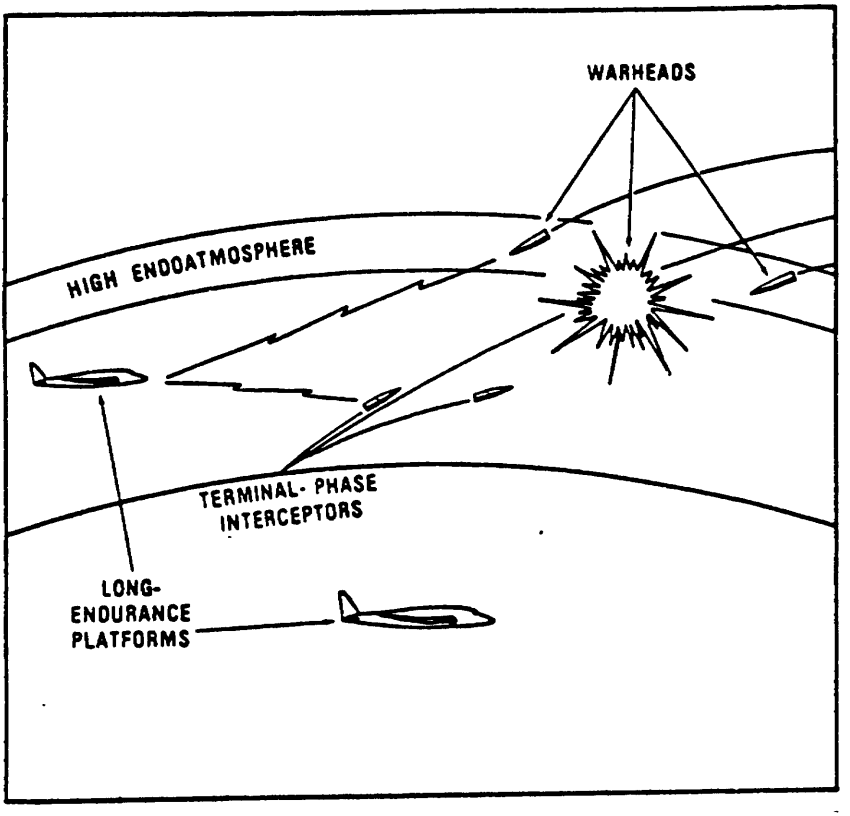


Figure 2: Strawman concept for ballistic missile defense during the terminal phase. This phase is the final line of defense. Threatening objects include warheads shot at but not destroyed, objects never detected, and decoys neither discriminated nor destroyed. These objects must be dealt with by terminal phase interceptors. An airborne optical adjunct is shown here. Reentry vehicles are detected in late exoatmospheric flight with sensors on these long-endurance platforms. The interceptors - nonnuclear, direct impact projectiles - are guided to the warheads that survived the engagements in previous phases.

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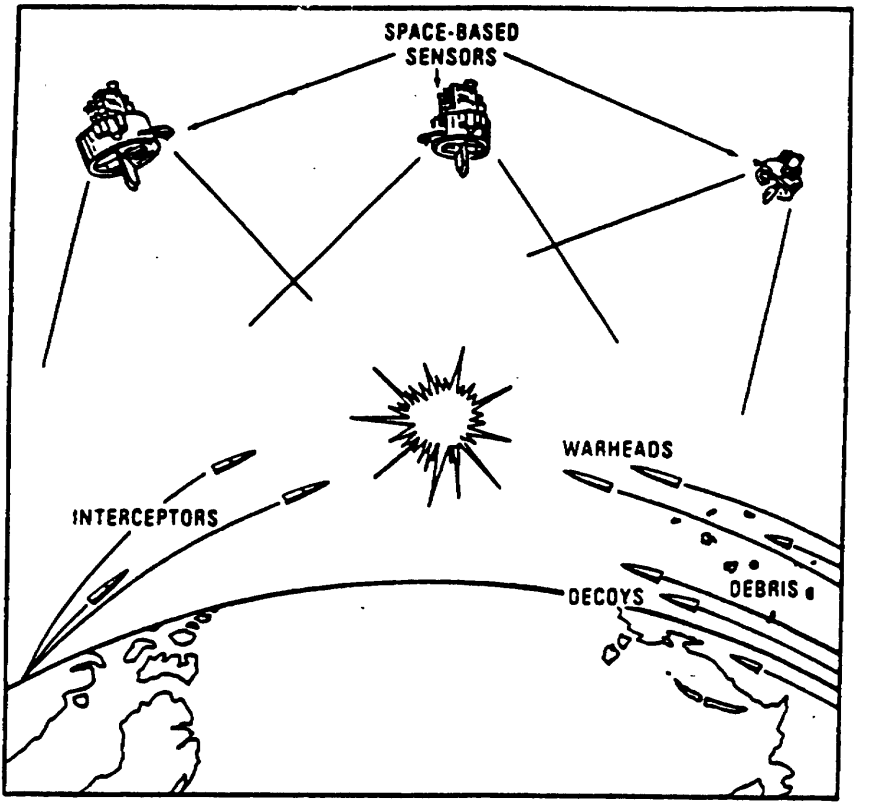


Figure 3: Strawman concept for ballistic missile defense during the midcourse phase. Intercept outside the atmosphere during the midcourse phase requires the defense to cope with decoys designed to attract interceptors and exhaust the force. Continuing discrimination of nonthreat objects and continuing attrition of reentry vehicles will reduce the pressure on the terminal phase system. Engagement times are longer here than in other phases. The figure shows space-based sensors that discriminate among the warheads, decoys, and debris and the interceptors that the defense has committed. The nonnuclear, direct impact projectiles speed toward warheads that the sensors have identified.

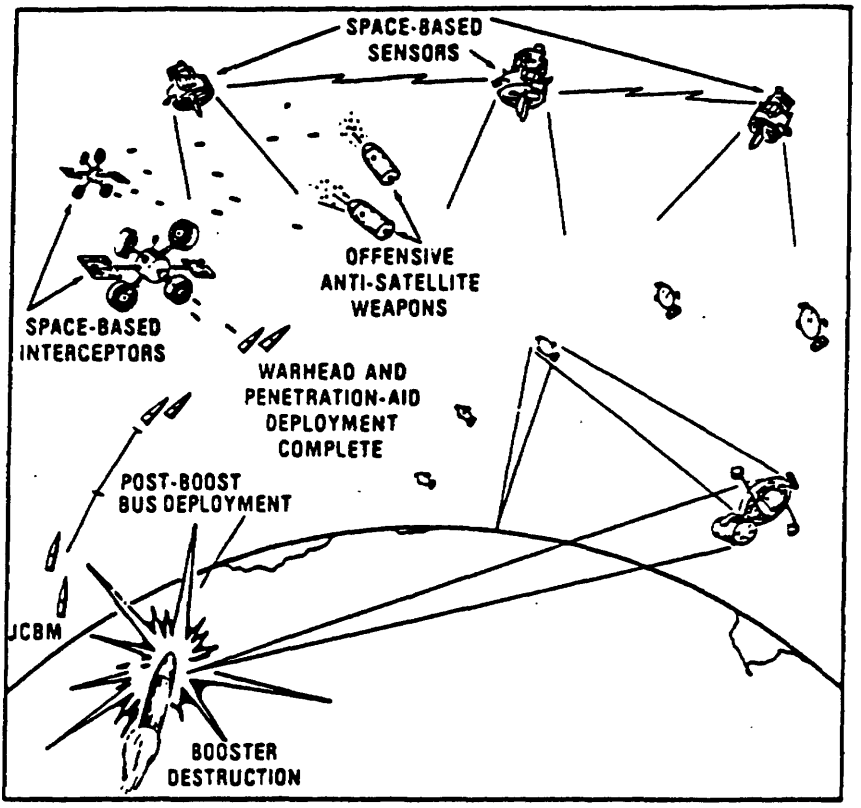


Figure 4: Strawman ballistic missile defense concept for boost-phase. An essential requirement is a global, full-time surveillance capability to detect an attack and define its destination and intensity, to determine targeted areas, and to provide data to boost-phase intercept weapons and post-boost vehicle tracking systems. Attacks may range from a few missiles to a massive, simultaneous launch. For every booster destroyed, the number of objects to be identified and sorted out by the remaining elements of a multitiered defense system will be reduced significantly. An early defensive response will minimize the numbers of deployed penetration aids. The transition (post-boost phase) from boost phase to midcourse allows additional time for intercept by boost-phase weapons and for discrimination between warheads and deception objects. Space-based sensors (three are shown at the top of the figure) detect and define the attack. Space-based interceptors (at the left in the figure) protect the sensors from offensive antisatellite weapons and, as a secondary mission, attack the missiles. In this depiction nonnuclear, direct impact projectiles are used against the offensive weapons.

The resources of the defense system include the sensors and weapons, the data-processing and communication gear, and the platforms or stations on which these and other components reside.

The allocation of defense system resources, both sensor and weapon, is a dynamic process that must be repeated with each significant change in the situation. Sensors must be assigned to sectors or to targets of interest at appropriate times to acquire necessary data, and weapons must be assigned to targets within a framework implemented by rules of engagement. An optimum allocation of resources involves extrapolating the present situation into the future and selecting a course of action that optimizes some quantity, for example, the number of targets destroyed. In each phase there are options available to the commander depending on the nature of the threat. The options also differ because events happen within different time frames.

Ultimately, data must be distributed to authorities external to the defense system to infer or sense the development of hostilities, to determine a defense condition level and take appropriate actions with respect to weapons release, to assist in inferring the attacker's intent, and to evaluate the effectiveness of the defense and anticipate damage.

Developing hardware will not be as difficult as developing appropriate software. Very large (order of 10 million lines of code) software that operates reliably, safely, and predictably will have to be deployed. Fault-tolerant, high-performance computing will be necessary. It must be maintenance-free for 10 years, radiation-hardened, able to withstand single-event upset, and designed to degrade gracefully. The main problem of network communication is managing networks of space-, air-, and ground-based resources. Other problems are real-time protocols

and dynamic reconfiguration. In addition, specific ballistic missile defense algorithms, for example, target assignment, as well as a simulation environment for evaluating architectures will have to be developed.

SURVIVABILITY

Survivability is potentially a serious problem for the space-based components. The most likely threats to the components of a defense system are direct-ascent antisatellite weapons; ground- or air-based lasers; orbital antisatellites, both conventional and directed energy; space mines; and fragment clouds.

The approaches to enhancing survivability against a determined attacker are the classic ones that have been used to enhance the survivability of aircraft and surface ships: hardening, evasion, proliferation, deception, and active defense. Applying these functions in combinations will be necessary to counter the spectrum of potential attacks.

Ideally, the defense system should be designed to withstand an attack meant to saturate the system, that is, to survive an attack requiring the commitment of all defense system resources.

OFFENSIVE RESPONSES

In all considerations of offense versus defense, there is a continuing dynamic interaction. Each action can stimulate a countermeasure. In response to the development of a ballistic missile defense system, history indicates that a potential opponent will, in general, proceed in a straightforward manner with the lowest level of countering technology judged adequate. There would be continual work on possible technical responses, and it

should be noted that each projected response involves a trade-off; for example, hardening of booster rockets means a reduced payload or range.

CRITICAL TECHNOLOGIES

The Defensive Technologies Study Team concentrated on critical technologies, that is, the technologies basic to the longest lead-time items in a multitiered, four-phase ballistic missile defense system capable of defending against a massive and responsive threat. The concern was primarily with the technologies that are paramount -- the concepts whose feasibility will determine whether an effective defense is possible.

There are several critical technological issues that will probably require research programs of 10 to 20 years.

- Boost and post-boost phases. As mentioned earlier, the ability to effectively respond to an unconstrained threat is strongly dependent on meeting it appropriately during the boost and bus deployment, or post-boost, phases. This is especially important for a responsive threat.

- Threat clouds. Large threat clouds -- that is, dense concentrations of reentry vehicles, decoys, and debris in great numbers -- must be identified and sorted out during the midcourse phase and high reentry.

- Survivability. It will be necessary to develop a combination of tactics and mechanisms ensuring the survival of the system's space-based components.

- Interceptors. By having inexpensive interceptors in the midcourse phase and in early reentry, intercept

can be economical enough to permit attacks on threat objects that cannot be discriminated.

- Battle Management. Tools are needed for developing battle-management software.

The study also identified 5- to 10-year research programs dealing with other issues. One category is space logistics. In order of priority within this category, it is desirable to have (1) a heavy-lift launch vehicle for space-based platforms of up to 100 metric tons, (2) a capability to service the space components, (3) a capability to make available, on orbit, sufficient materials for space-component shielding against attack, and (4) an ability to transfer items from one orbit to another. In addition to these items, multimegawatt power sources for space applications would be required.

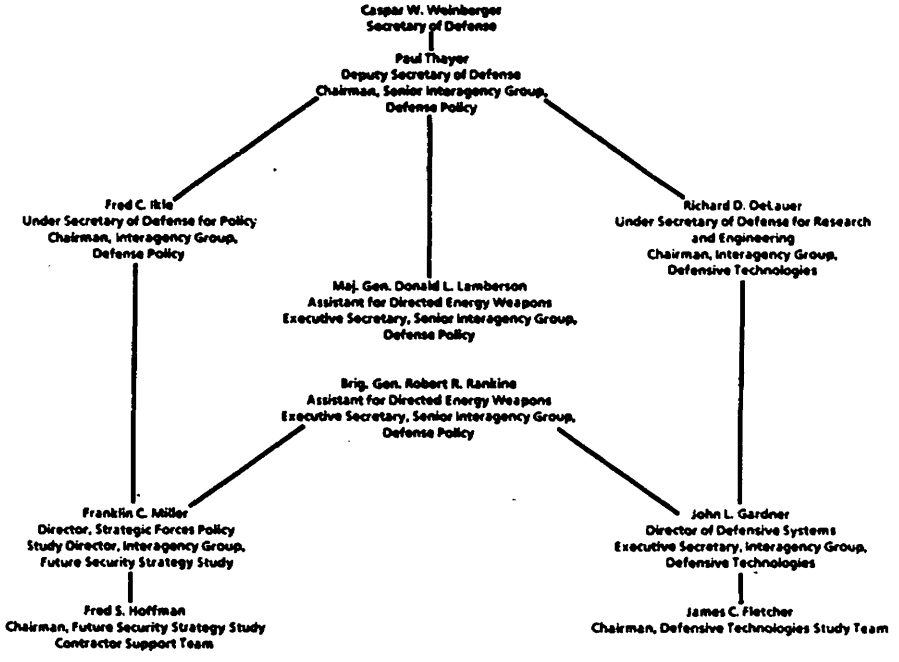
NEAR-TERM DEMONSTRATIONS AND DEPLOYMENTS

An informed decision on system development cannot be made before the end of the decade, but there may be reasons for near-term feasibility demonstrations that could be developed into elements of a total ballistic missile defense system. Unlike the boost and post-boost phases, the trade-offs between competing technological approaches for the midcourse and terminal phases are relatively well understood. Although we cannot yet pick detailed designs for the major components of the midcourse and terminal-phase defenses, the best generic approaches are known and the set of competing technologies is narrow. A number of near-term demonstrations could be done before the end of the decade that typify technological milestones. Such demonstrations could include, among others, a space-based acquisition, tracking, and pointing experiment; a megawatt-class, visible-light, ground-based laser demonstration; an airborne optical adjunct demonstration; and a high-speed, endoatmospheric, nonnuclear interceptor missile demonstration.

In the next five years there are decision points that will affect the technologies available by 1990. Between 1990 and 2000 the United States may decide to provide increasing protection for its allies and itself by deploying portions of the complete four-phase system. Such deployments might be evolutionary, leading to the final, low-leakage system.

The members of the Defensive Technologies Study Team finished their work with a sense of optimism. The technological challenges of a strategic defense initiative are great but not insurmountable. By pursuing the long-term, technically feasible research and development plan identified by the Study Team and presented in this report, the United States will reach that point where knowledgeable decisions concerning an engineering validation phase can be made with confidence. The scientific community may indeed give the United States "the means of rendering" the ballistic missile threat "impotent and obsolete."

ORGANIZATION



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Study Team Leadership

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Dr. Robert C. Sepucha	Defense Advanced Research Projects Agency
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Countermeasures and Tactics Panel

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Dr. Harry I. Davis	Private Consultant
Mr. J. R. Logie	Private Consultant
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Executive Scientific Review Group

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Dr. Solomon J. Buchsbaum	Bell Laboratories
Mr. Daniel Fink	Private Consultant
Mr. Bert Fowler	Mitre Corporation
Dr. Eugene Fubini	Private Consultant
Admiral Bobby R. Inman	United States Navy (Retired) - Microelectronics and Computer Technology Corporation
Dr. Michael May	Lawrence Livermore National Laboratory
General E. C. Meyer	United States Army (Retired)
Professor William A. Nierenberg	Scripps Institute of Oceanography
Mr. David Packard	Hewlett Packard Company

GLOSSARY

active sensor	A system that includes both a detector and a source of illumination. A camera with a flash attachment is an active sensor.
airborne optical adjunct	A set of sensors designed to detect, track, and discriminate an incoming warhead. The sensors are typically optical or infrared devices flown in an aircraft stationed above clouds.
algorithm	Rules for solving a problem using computer language.
architecture	The physical structure of a computer system, which can include both hardware and software (programs).
birth-to-death tracking	The ability to track a missile and its payload from launch until it is intercepted or reaches its target.
boost phase	The portion of a missile flight during which the payload is accelerated by the large rocket motors. For a multiple-stage rocket, boost phase involves all motor stages.
booster	The rocket that "boosts" the payload to accelerate it from the earth's surface into a ballistic trajectory, during which no additional force is applied to the payload.

bus deployment phase	The portion of a missile flight during which multiple warheads are deployed on different paths to different targets (also referred to as the post-boost phase). The warheads on a single missile are carried on a platform or "bus" (also referred to as a post-boost vehicle), which has small rocket motors to move the bus slightly from its original path.
chemical laser	A laser in which chemical action is used to produce the pulses of coherent light.
coherent light	The state in which light waves are in phase over the time scale of interest. Light travels in discrete bundles of energy called photons. Each photon may be treated like an ocean wave. If all the waves are in phase, they are said to be coherent. When light is coherent, the effects of each photon build on top of the others. A laser produces coherent light and therefore can concentrate energy.
cold bodies	Objects at or near low ambient temperature, which radiate infrared radiation. All objects radiate electromagnetic energy, and if the object is hot enough, this energy is visible light.
constrained threat	A situation where opponents are limited in the number of warheads or types of missiles, for example, by arms control agreement.

continuous-wave laser	A laser in which the coherent light is generated continuously rather than at fixed time intervals.
decoy	A device that is constructed to look and behave like a nuclear-weapon-carrying warhead, but which is far less costly, much less massive, and can be deployed in large numbers to complicate defenses.
directed energy	Energy in the form of particle or laser beams that can be sent long distances at nearly the speed of light.
discriminate	The process of observing a set of attacking objects and determining which are the real warheads and which are decoys and other nonthreatening objects.
dynamic reconfiguration	A means whereby a battle-management system can change its condition during a battle to respond to changing circumstances, such as the destruction of some defensive components.
electromagnetic gun	A gun based on the idea of an open solenoid. The projectile is accelerated by electromagnetic forces rather than by an explosion, as in a conventional gun.
endoatmospheric	When all activities take place within the earth's atmosphere, generally considered as occurring at altitudes below 100 kilometers.

excimer laser	A chemical laser that uses noble gases.
exoatmospheric	When all activities take place outside the earth's atmosphere, generally considered as occurring at altitudes above 100 kilometers.
fragment clouds	Clusters of small objects placed in front of a target in space. This is a simple way to destroy the target.
free-electron laser	A laser in which electrons are converted to coherent light. The electrons are supplied by an accelerator and power for the laser by electrical energy.
hypervelocity gun	A gun that can accelerate projectiles to 5 kilometers per second or more, for example, an electromagnetic, or rail, gun.
imaging	The process of identifying an object by obtaining a high-quality image of it.
infrared sensor	A sensor to detect the infrared radiation from a cold body such as a missile reentry vehicle.
Interagency Groups	Two groups, one for Defensive Technologies and one for Defense Policy, set up to monitor the work of each study team.
intercept	The act of destroying a target.
kinetic energy	The energy from the momentum of an object.

laser	A device for generating coherent visible or infrared light.
laser designator	The use of a low-power laser to illuminate a target so that a weapon equipped with a special tracker can home in on the designated tar et.
laser imaging	A new technology where a laser beam can be used in a way similar to a radar beam to produce a high-quality image of an object.
laser tracker	The process of using a laser to illuminate a target so that specialized sensors can detect the reflected laser light and track the target.
leakage	The percentage of warheads that get through a defensive system intact and operational.
midcourse phase	The long period of a warhead's flight to its target after it has been dispensed from the post-boost vehicle until it reenters the atmosphere over its target.
multispectral sensing	A method of using many different bands of the spectrum to sense a target, for example, visible and infrared light. If several bands are used, deceptive measures become much more difficult.
neutral-particle beam	An energetic beam of neutral atoms (no net electric charge). A particle accelerator moves the particle to nearly the speed of light.

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particle beam	A stream of atoms or subatomic particles (electrons, protons, or neutrons) accelerated to nearly the speed of light.
passive sensor	A sensor that only detects radiation naturally emitted (infrared radiation) or reflected (sunlight) from a target.
penetration aids	Methods to defeat defenses by camouflage, deception, decoys, and countermeasures.
post-boost vehicle	The portion of a rocket payload that carries the multiple warheads and has maneuvering capability to place each warhead on its final trajectory to a target (also referred to as a "bus").
radiant energy	The energy from radiation such as electrons, protons, or alpha particles.
real-time protocols	Computer programs capable of making decisions as rapidly as input information is received.
repetitively pulsed laser	A laser that fires its beam in sequential short bursts, as opposed to a continuous beam or a single pulse.
Senior Interagency Group	Set up in response to the President's directive to study the ballistic missile defense problem. The group reported to the National Security Council and consisted of senior representatives from the Department of Defense, the Department of State, the Arms Control and Disarmament Agency, the

	Central Intelligence Agency, the National Aeronautics and Space Administration, the National Security Council, and the Office of Science and Technology Policy.
signal processing	A computer system's capability to organize the raw data received from many different sources.
single-event upset	Electronic components of a battle-management system performing abnormally because of radiation.
structured attack	Timing the arrival of a sequence of warheads at their targets to create maximum destructive effects.
terminal phase	The final phase of a ballistic missile trajectory, during which warheads and penetration aids reenter the atmosphere.
threat clouds	Dense concentrations of both threatening and nonthreatening objects. The defense must distinguish between them.

Senator PRESSLER. I thank this panel. And if the next panel would wait just a moment, I will have a conference with Senator Tsongas on the timing.

[Pause.]

Senator PRESSLER. I would ask the second panel tc please come forward at this time. Senator Tsongas will ask his questions of you, because he cannot be here this afternoon. I shall be back at 2. We ought to give them a chance to have lunch.

Senator TSONGAS. Oh, no. [General laughter.]

Senator PRESSLER. And we will continue this afternoon. But to accommodate Senator Tsongas, I would ask the second panel to come forth at this time to respond to his questions.

You will be through by 1:30 or so, and I would ask staff to help them get into a restaurant here, and we will start again at 2. So please go ahead.

[Pause.]

Senator PRESSLER. May we keep the noise down, please?

Senator TSONGAS [presiding]. My difficulty, and I apologize for imposing on you like this, is I will not be able to be here at 2, since I assumed this would be just a morning exercise. I would simply like to ask you some questions, and then at 2, if you would come back, we will go through the normal testimony.

I hope that would be acceptable.

If we can leave aside the issue of whether the administration is going to negotiate or not, which is left to everyone's individual judgment, but since you have expertise in technology, I would like to address just that part of it in followup to what was said earlier.

Let's deal with the last issue first: the vulnerability of an SDI system in space. And what would be the likely response of either nation, were such a system to be deployed? And, finally, what are the technical advantages offered to a nation willing to engage in first strike, predeployment and postdeployment of such a system?

[Dr. Drell's biographical data follows:]

BIOGRAPHICAL DATA OF DR. SIDNEY D. DRELL

PRESENT POSITION

Lewis M. Terman Professor, Deputy Director, and Executive Head Theoretical Physics, Stanford Linear Accelerator Center; Co-Director, Center for International Security and Arms Control, Stanford University, Stanford, California.

PRESENT ACTIVITIES

Consultant, President's Foreign Intelligence Advisory Board.
Consultant, Office of Technology Assessment, U.S. Congress.
Consultant, Los Alamos Scientic Laboratory.
Member, Board of Directors, The Arms Control Association, Washington, D.C.
Member, High Energy Physics Advisory Panel, U.S. Department of Energy (formerly AEC and ERDA), Chairman 1974-82.
Member, JASON Division, THE MITRE Corporation (former member of JASON Steering Committee).
Member, Board of Governors, Weizmann Institute of Science, Rehovot Israel.
Member Advisory Committee, MIT Physics Department.
Member, Board of Directors, "Annual Reviews, Inc.".
Member Council on Foreign Relations, New York.
Member, Advisory Board, Institute for National Strategy, Los Angeles, California.
Vice President, American Physical Society.

PROFESSIONAL AND HONORARY SOCIETIES

American Physical Society.
National Academy of Sciences.
American Academy of Arts and Sciences.
Phi Beta Kappa.
Sigma Xi.
Phi Kappa Phi.

AWARDS AND HONORS

Ernest Orlando Lawrence Memorial Award—1972—for research in Theoretical Physics (Atomic Energy Commission).
University of Illinois Alumni Award for Distinguished Service in Engineering—1973. Guggenheim Fellowship—1961-62 and 1971-72.
Richtmyer Memorial Lecturer to the American Association of Physics Teachers, San Francisco, California—1978.
Leo Szilard Award for Physics in the Public Interest—1980—presented by the Forum on Physics and Science of the American Physical Society.
D.Sc. (Honorary), University of Illinois, Chicago Circle—1981.
1983 Honoree of the Natural Resources Defense Council for work in arms control.

RECENT POSITIONS AND ACTIVITIES

Spring 1984—I. I. Rabi Visiting Professor, Columbia Univ., New York.
Spring 1983—Danz Lecturer, University of Washington, Seattle.
1974-83—Member Board of Trustees, Institute for Advanced Study Princeton, New Jersey (currently emeritus).
1978-82—Consultant, Senate Select Committee on Intelligence.
1977-82—Consultant, Office of Science and Technology Policy.
1973-81—Consultant, National Security Council.
1969-81—Consultant, U.S. Arms Control and Disarmament Agency.
1978-80—Member, Energy Research Advisory Board, U.S. Dept. of Energy.

STATEMENT OF DR. SIDNEY D. DRELL, DEPUTY DIRECTOR, STANFORD LINEAR ACCELERATOR, STANFORD, CALIF.

Mr. DRELL. Senator, as far as the vulnerabilities are concerned, even if all the technical goals of the administration's and the Defense Department's Strategic Defense Initiative were achieved, it would still face its most difficult problems, which are the operational ones; namely, that the parts of the system that are in space are vulnerable to various countermeasures, the easiest of which would be space mines that could be launched and positioned in orbits near the satellites, and detonated upon command from ground. They also would be less expensive. The satellite platforms such as laser-based platforms certainly are more fragile than the ICBM's they are designed to intercept.

And so the operational problem of vulnerability of space-based systems seems to me an unavoidable one for space-based systems. For the popup systems that you mentioned in your questions earlier today, you can avoid the vulnerability for the interceptors or for the directed energy weapons like the X-ray lasers, but not for the sensors that must always be in space. For popup systems, the problem, as you so clearly focused on during your earlier discussions, is one of available time.

You have less than 3 to 5 minutes to have your system not only launched, but itself rise above the atmosphere, because the X-rays are absorbed by the atmosphere. At most, there are only seconds to make the decision to launch. Although there are 3 to 5 minutes for boost phase now, less than 1 minute would be required should the Soviets modify their missile force with technology available and

use hot burn, so the booster finishes its burn before it reaches the top of the atmosphere—you have the unavoidable problem that with hot burn, there is no possibility of intercept during boost phase.

So I think the problems of the defense—in contrast to, say, going to the Moon—are operational ones. In the case of the Moon, you knew there was one Moon, you knew where the Moon would be. We are now dealing with an offense that has countermeasures available to it, whether it is to attack the space platforms with space mines, harden the missiles against them with material to weaken the effect of the lethal rays, or by faster burn and a doctrine just to deny time totally. Even with the computers doing their best, you have a problem that the Moon shot did not have.

It seems to me this operational problem is the most severe one for an effective defense that will meet the President's goal of making nuclear weapons obsolete and impotent. And there is plenty of time during any development for the relatively easier steps with space mines to keep anything in space highly vulnerable as long as we do not have an ASAT treaty.

Senator TSONGAS. Mr. Carnesale.

[Mr. Carnesale's biographical data follows:]

BIOGRAPHICAL DATA OF ALBERT CARNESALE

ADDRESSES

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PRESENT POSITION

1974-present. Harvard University, Cambridge, Massachusetts. Professor of Public Policy and (since 1981) Academic Dean at the John F. Kennedy School of Government. Research and teaching interests are in international security and arms control, with emphasis on policies associated with nuclear weapons and strategies for their use and non-use, on international issues associated with nuclear energy, and on the impact of technological change on defense and arms control policy.

PREVIOUS POSITIONS

1972-1974. North Carolina State University; Raleigh, N.C. Professor and Head, Division of University Studies, and University Coordinator for Environmental Studies. Responsible for university-wide interdisciplinary programs dealing with contemporary issues and problems.

1969-1972. U.S. Arms Control and Disarmament Agency; Washington, D.C. Chief, Defensive Weapons Systems Division, and senior advisor to head of U.S. Delegation to Strategic Arms Limitation Talks (SALT).

1962-1969. North Carolina State University; Raleigh, N.C. Instructor, Assistant Professor, and Associate Professor of Nuclear Engineering.

1957-1962. Martin Marietta Corporation; Baltimore, Md. Senior Engineer; Nuclear Division.

OTHER PROFESSIONAL ACTIVITIES

Consultant to U.S. Arms Control and Disarmament Agency and Departments of Defense, Energy and State.

U.S. member of (and head of U.S. Delegation to) the Technical Coordinating Committee of the International Nuclear Fuel Cycle Evaluation (1978-1980).

EDUCATION

B.M.E.—(Mechanical Engineering), The Cooper Union, 1957.
M.S.—(Mechanical Engineering), Drexel Institute, 1961.
Ph.D.—(Nuclear Engineering), North Carolina State University, 1966.

A.M.—(Honrary), Harvard University, 1979.

RECENT PUBLICATIONS

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STATEMENT OF ALBERT CARNESALE, PROFESSOR OF PUBLIC POLICY AND ACADEMIC DEAN, JOHN F. KENNEDY SCHOOL OF GOVERNMENT, HARVARD UNIVERSITY, CAMBRIDGE, MASS.

Mr. CARNESALE. Let me try to address both of your questions. One, how the vulnerability of a strategic defensive system in space compares to the vulnerability of the missiles that it is intended to attack; and second, what that does to the propensity for a first strike.

There is no fundamental physical principle that says that a missile will be more vulnerable than a satellite in space. However, every scientist or engineer whom I have asked this question—which side would you rather be on, the side whose job it is to shoot down the satellite, or the side whose job it is to use the satellite to shoot down the missiles?—prefers to be on the side whose job it is to shoot down the satellite. Without exception. They do not say that the outcome is absolutely certain, but their preference is clear. Any space-based defense is likely to be more vulnerable than the things it is trying to attack.

As for thinking about a popup system, one must avoid the fallacy of the last move. If we have a popup system that can destroy their missiles in their boost phase, they might have something similar. Suppose they have a popup system, no matter how crude, that is forward-based, say, in their submarines. They know in advance when they are going to launch their offensive missiles and, just before they do so, they pop up a system whose sole function it is to shoot down our popup system. It is easier for them than for us, because they control the timing of events. They are not going to be surprised if they are starting a war.

Senator TSONGAS. Wait a minute. Are you saying that the Soviets could deploy a popup system that could counter——

Mr. CARNESALE. I am saying that, if we could deploy a popup system, they could probably deploy a popup system to destroy ours. Let me put it this way: I am not going to bet my country on the certainty that they cannot.

Senator TSONGAS. But you could not assure us that we could not develop an antipopup popup system?

Mr. CARNESALE. It is harder for us than it is for them, because we would have only 3 minutes to get their boosters. All their popup system has to do is hold ours down for 3 minutes.

Senator TSONGAS. Well, what about the first strike?

Mr. CARNESALE. Imagine the worst situation; that is, let us assume that both sides have "Star Wars" systems in space, and let

us assume even further, as long as we are on this flight of fantasy, that these systems are reasonably effective as ballistic missile defenses.

If they are reasonably effective as ballistic missile defenses, the odds are they are far more effective as antisatellite weapons, because that is a much easier task. This means they are vulnerable to attack by each other.

Now, think of the incentive to go first. By attacking the other fellow's "Star Wars" satellites, you accomplish two things simultaneously. First, his nation is now vulnerable to your offensive missiles, because you have destroyed his defense; and second, your nation remains invulnerable to his offensive systems, because you have retained your defense. So if these things work, I can think of nothing less stable than for both countries to have them simultaneously.

Senator TSONGAS. So, as to the desirability of first strike, it is the function of how effective a system is?

Mr. CARNESALE. It is a function of how effective it is, but if it is reasonably effective, as the proponents would have us believe, then it maximizes the incentive on both sides. Imagine what would happen if you were struck first. You would suddenly find yourself in a situation where you were vulnerable to his offensive weapons and he was not vulnerable to yours.

That is a situation in which I would not like to find us. That is a situation in which the Soviets would not like to find themselves. For both sides to have space-based defenses would be the worst of all situations. It is worse than the situation you asked about: One where they were starting to deploy such a system and we felt compelled to destroy it.

Senator TSONGAS. Do you want to comment on that, Dr. Drell?

Mr. DRELL. I would say that I agree with Dr. Carnesale's statement. The fact is that a leaky umbrella does you more good if you are protecting yourself against a drizzle than a downpour. If you have this combination of offense and a partially effective defense—which, by the way, is what the Defense Department is now speaking of—they don't in their plans speak of making weapons obsolete and impotent only; they give emphasis in the 5-year plan that you have received to enhance deterrence with a partially effective defense. But with a partially effective defense, you have to recognize that it will be more effective as an adjunct of a first strike, because the retaliatory force will be at a predictable time, with reduced coordination, reduced in intensity, and you will, with a leaky umbrella, be protecting yourself more against the drizzle than a downpour.

That is exactly the way it was viewed in 1972, when President Nixon abandoned plans to build a nationwide ABM defense. He said we could not do it, and the effort would be destabilizing just because of this reason. I think that nothing has changed in the 15 years since then. And it is also clear that the Under Secretary of Defense, who is not here this morning, agrees with this statement because, as he has said in the New York Times, "With unconstrained proliferation, no defensive system will work."

The only path, it seems to me, to better stability is by, first, through arms control, limiting the offenses and constraining the

countermeasures by limiting technology in a verifiable way and reducing numbers in a verifiable way, and then one can think of perhaps improving the stability or decreasing the danger of the world, as the President called for through a mutually implemented defense initiative.

Senator TSONGAS. Ambassador, I am not familiar with your technical background. Would you care to comment on those questions that I posed?

STATEMENT OF AMBASSADOR ROBERT W. BUCHHEIM, U.S. REPRESENTATIVE TO THE 1978–79 UNITED STATES-SOVIET UNION ASAT TALKS, PHOENIX, ARIZ.

Ambassador BUCHHEIM. I would make just two brief remarks, Senator. One is, that in my opinion, deployment of a space-based ABM system will not take place totally and instantly, these things, whatever they are, will be put up one at a time. The incentive to shoot at them one at a time, when they are on their way, would be very high. So, it seems to me, anyone interested in space-based ABM defenses really ought to be seriously interested in the best kind of ASAT prohibitions we can get, because his system, strong as he may desire it, is going to get blown up by any ASAT system in the other guy's hands.

Now, a second point is, I would like to return to Mr. Perle's comment about the difficulties of dealing with an effective ASAT prohibition because, as he said and as many people have said, getting away with having only a few clandestine ASAT systems on hand is a much more serious matter than, say, keeping a few ICBM's or keeping a few chemical weapons or whatever.

Now, that statement is correct and important when you recognize that the vital U.S. satellite assets that are in operation today are very few in number, and our capacity to replace them, if they are taken out, is almost zero in terms of doing anything in an interesting timespan.

On the other hand, the argument about the importance of being able to keep to the side a few ASAT contraptions is not vital when you play it against the kind of numbers of things in orbit that would be fundamental to any effective space-based ABM system.

So if the Soviets could hide—what—three or five ASAT interceptors like that, that is a very serious problem for our present space assets. It's a trivial matter against the number of objects that would be put into orbit as part of an ABM system. So the problem is really different.

Senator TSONGAS. I promised I would let you get out of here in time to have lunch. I have just one other question.

Where did this idea come from? I mean, it just appeared on the scene, and obviously there were discussions on technologies for years, but in terms of concept it suddenly becomes American national policy within the scientific and technical community. What, as far as you know, preceded the President's announcement of March 23 or whatever that date was of last year?

Ambassador BUCHHEIM. I think I could cast a little light on that. It was way back in the 1950's when studies were undertaken within the Air Force, and by some of the contractors, on what was

then called SPAD—you have to have an acronym for everything. SPAD is an acronym for space-based anti-something-or-another defense. So the idea is ancient. It was studied to death. The Air Force said, oh, forget it; it is not worth the candle.

I would guess—and I think I could prove this if I took the trouble to go back through old writings—that the people at Penmunde before and during World War II had such notions. You remember, one of those notions, as I recall, was to get up with a manned spaceship and unroll gigantic metal foil reflectors to focus the sun's rays in such a way that they could burn the British out of London.

So these ideas go back—and I would also bet $4 of my own money that Leonardo da Vinci had such notions.

Senator TSONGAS. Well, I hope that your last proposal is stricken from the record before somebody reads it and proposes it. Do you think we could actually burn Moscow like that?

Ambassador BUCHHEIM. Assuming you can do all the things that would be precedent to that stunt, yes, you could probably set fires in Moscow. I do not know whether that would help them or hurt them; it gets pretty cold there. [General laughter.]

Mr. CARNESALE. We must realize that defense has had strong appeal to every President, especially after about the first year and a half in office. It has been my experience when they suddenly sit up one day and say, "Wait a minute, let me make sure that I have this straight. I am responsible for the lives of roughly 200-and-some-odd million people here, and you are telling me that if the Soviets want to kill them all, they can do it and there is nothing I can do about that." An adviser says, "Well, yes, that is right, sir," to which the President responds, "You change that. Come back with an idea that changes that."

Now, this time, somebody had an old idea, with a new wrinkle on it, that got a lot of public press, High Frontier. General Danny Graham and the other authors of that project offered "assured survivability" rather then "assured destruction." It is not surprising that this would be attractive to any President. If he were to ask some scientists whether anything has changed to make this goal achievable, they might mention some of the things going on at the National Laboratories, in particular, progress in X-ray lasers. That was really exciting science, but it scared the hell out of engineers to think of actually building a system based on this science.

The President has a science advisor; he does not have an engineering advisor. It is not surprising that a scientist would be more optimistic than an engineer about the prospects for defense. Also, it is not evil to want to defend the people rather than to have them be vulnerable. This goal, I believe, passes through the head and the heart of every President.

The hard questions about a defense initiative relate to the selection of programs, their costs and benefits, the risks associated with them, and so on.

Senator TSONGAS. Before you get off that, the 85-percent figure is fascinating. I just sat back here with a calculator and went through that, and it would only let one missile through. Where did the 85-percent figure come from?

Mr. CARNESALE. I think the more interesting question is where did the five layers come from? It used to be three layers. I can

imagine where both numbers came from, though, I was not there at the time. What effectiveness do you need to get down to one warhead with three layers? The answer is about 98 percent. That is too high; they would laugh us out of the room. Try 85 percent. But 85 percent will not do it with three layers. How many does it take? Five layers. So the answer is five. [Laughter.]

Senator TSONGAS. But let us put ourselves in his shoes. Everyone is saying this thing has been oversold. Now, the only figure that was referred to at all in the entire morning was the 85 percent through five layers, and that is a 99.99 percent effective system.

Is that, from a science or engineering perspective, a—not credible—but justified? Can someone with a serious technical background use a figure like that in this context legitimately?

Mr. CARNESALE. Not that I know of. But more importantly—and I just want to say this one thing—these are not five completely independent systems. It is wrong, mathematically, to say that the probability of leakage is the probability of penetrating through five independent systems each of whose likelihood of intercept is .85. Do they not share, for example, sensors in common?

Suppose your satellites get shot down—your sensor satellites. Let me tell you, that boost-phase system is not going to do anything, and neither is either leg of mid-course intercept. So three systems just went to zero from .85. The layers are not independent. The real defense would be far less effective.

Senator TSONGAS. If they made you the "Star Wars" czar, you would say the same thing, wouldn't you?

Mr. CARNESALE. I have great respect for General Abrahamson for taking that job. It is a job I would not touch. But if you asked if I would be willing to try to develop eventually a defense for this country, which in my view would have to be coupled with arms control on offensive weapons, so that we could move away from this fragile shield of deterrence based on offense dominance, the answer would be yes. But I certainly would not promise that I could do it.

Mr. DRELL. I have two comments, if I may, after that. First, one is dealing with a system with thousands of sensors and platforms and elements that will never have been tested under battle conditions, and so to give probability numbers or even, what is more important, to try to give some idea of confidence in what the system can or will do is meaningless.

Second, there is the point that there are common technology failures. You just cannot multiply numbers like that together. Previous to this morning's testimony, the common chart that Aviation Week showed had four layers, each 90 percent effective, which also gives you 1 warhead out of 10,000. I am not sure which one you want to accept.

Senator TSONGAS. Wouldn't it be cheaper to have one system that was 99.99 percent effective?

Mr. DRELL. I think you can picture it that way, but the fact is, when you look at each layer of these defense systems, whether it is the boost phase, post-boost phase, or midcourse phase, you run into monumental problems that you do not know how to solve, and so you start multiplying small numbers together. That is the nature

of the analysis right now, and I think General Abrahamson was quite fairly presenting it that way.

What seems to be hidden in all of this is, it is not just an innocuous defense R&D program which the President has called for. He has called for a fundamental change in the strategic relationship between the United States and the Soviet Union. We have been doing R&D on advanced technology for defensive systems as a prudent hedge against technology breakthroughs, against Soviet programs, and the potential for Soviet unilateral moves.

I believe that has been a relatively well run program, and a wise one, at about the right level. The President has now said this is R&D toward a Presidentially directed goal to change the fundamental relationship between these two countries, and we have to ask not only can we do it—and there is a lot of skepticism, clearly today, on the technical ground—but what is the effort going to do with the stability of our strategic relations, to arms control, to the likelihood of avoiding a nuclear war.

At the moment, it is a unilateral change, and the Soviets are going to have to respond in accordance with their perception of what we might do. They cannot wait 10 or so years down the road for us to decide that "the emperor has no clothes" and we cannot build this system. They have to react now, and we get into a new cycle, just as we did with MIRV's 15 years ago.

Senator TSONGAS. Well, if you look at the hysteria in the United States when Sputnik was launched, you can imagine an equivalent hysteria.

Since you have to eat and I have family obligations that are imposing on me here, let me ask one final question. Would not the deployment of a "Star Wars" system compel the other side to increase the number of missiles and warheads overwhelmingly? Is that not, by definition, inconsistent with START?

Mr. DRELL. I believe it is. I think that to face the Soviets on the one hand with the proposal to reduce warheads—that is START—deep reductions in their most reliable deterrent force, their ICBM's, and at the same time to start down a Presidentially directed goal to neutralize those systems is just a logical inconsistency. So I see no way of the reductions of START being advanced or pushed forward, at the same time we are talking about a defense to neutralize that force unless arms control first limits, reduces the Soviet threat so that, even technically, you can think about a marginal defense, and establishes a cooperative regime so that you do not translate unilaterally taken moves into arguments for further buildings, as the MIRV proved to be. I think it is absolutely the wrong way to go. We need the arms control first.

Senator TSONGAS. What I find fascinating about all of this is, these arguments strike me as being the same as those we used to go through with SALT II. I mean they are fascinating, but the human factor intrigues me a lot more.

Why isn't it that in the Pentagon, where you obviously have enormous capability, technical capability, that someone does not simply say, you know, this thing is really a turkey?

Now, I suppose you would go through the same thing; 85 percent of the people at one level will not say it, and 85 percent of those at another level will not say it, so the chances are 99.99 that no one is

going to say to the President of the United States, "Mr. President, this thing is a turkey."

But I mean, in terms of how decisions are made internally at the Pentagon, where is the safety valve to say this is inappropriate at this level of expenditure, enormous consequences in terms of instability? Where within the Pentagon is the safety valve to argue what you have been arguing and others have argued for a long time now?

Mr. DRELL. It seems to me you saw some of that argument in front of you this morning for 3 hours. I heard the Pentagon come forward and speak about an R&D research and technology program, somewhat obfuscating the fact that this decision or commitment to a deployment is far off of their turf. As a free outside critic, I seem to have more freedom to do and say that I see wrong parts of the program.

Part of the confusion this morning was, I thought, some Pentagon people were trying to say, well, it is only a research and technology program; that is all it is.

Mr. CARNESALE. I would like to comment on that as well. First of all, the President's speech of March 23 only called for a research program consistent with the ABM Treaty. The defensive systems community then tried to put everything they could under that tent, and so you see this attempt to achieve an enormous expansion of activity. I think it has been held down remarkably well by people who do not have special interest in defensive systems. Indeed, if the House cut of $400 million survives, it is unclear whether the President's Strategic Defense Initiative will result next year in an increase or a decrease in the amount of spending for ballistic missile defense programs. It is close, if the $400 million cut sticks.

There are reasonable people working on this problem. They are putting all strategic defense programs together under one unbrella. There is no large increase in funding. There cannot be until you start to build things, and now we have nothing to build.

Senator TSONGAS. You know, this morning I was trying to think of an analogy, because the response of General Abrahamson was the President is giving me this challenge and I am going to meet it. If I were President, and I said I want you to go out and refrigerate the Arctic, and give them some obligation—I mean I suppose we could do it, but what exactly is the purpose of doing something like that? Does anybody ever suggest that—well, it seems to me that the threat of this system is not only in arms control, it is a threat in terms of taking engineers and capital away from other things that we need to be competitive internationally.

It also means a serious impact on the deficit issue, that it hurts the United States to pursue this particular approach. And I just wish there were people who were willing to bring the bad news to the President.

Mr. CARNESALE. But, Senator, I disagree to some extent. I do not believe it is wrong or evil to pursue the research. One reason is to hedge against Soviet defensive systems, so that we understand the technology better and can react.

Senator TSONGAS. We do not differ on that.

Mr. CARNESALE. None of us do. The question is about deployment. It is only the most extreme proponents of this initiative who talk in terms of deployment. Anybody who thinks about it knows that we do not know what we would deploy anyway. So I do not think the research program is evil. I favor the Strategic Defense Initiative.

What I do not favor is promising too much and getting ourselves committed to proceeding with something that may be contrary to our interests. We should be wary of ripping apart the ABM Treaty, which is the one thing that constrains Soviet defensive system.

Mr. DRELL. I have to respectfully disagree with my colleague, Dr. Carnesale here. I do not favor the Strategic Defense Initiative because it is toward a Presidentially directed goal. There are Presidential words in that speech to change the fundamental strategic relationship between the United States and the Soviet Union.

I submit that that is not just a research and technology program as it should be. I think that is where one has to watch out what the country is getting committed to.

Mr. CARNESALE. You are right; we disagree. I would like to see the relationship changed. My problem is that I have not got the foggiest notion of how to do it.

Mr. DRELL. Therefore, we do R&D. We do not have Presidentially directed goals.

Mr. CARNESALE. The goal is a worthwhile one, and I agree with it.

Senator TSONGAS. Well, you know, in the circles in which you all exist, I am sure there is a disrespect for fast food, but today you can appreciate the fact that there is such a thing.

I appreciate your coming. Thank you.

[Whereupon, at 1:36 p.m., the hearing recessed, to reconvene at 2 p.m. this same day.]

AFTERNOON SESSION

The committee met, pursuant to recess, at 2:10 p.m., in room SD-419, Dirksen Senate Office Building, Hon. Larry Pressler presiding.

Present: Senators Pressler and Pell.

Senator PRESSLER. We thank the members of the panels very much for their patience today. This is such an important issue that I think it merits the time we are putting into it. Also, I think this is the last major hearing before the Senate debates this issue on the floor, this committee having passed my resolution, which will be debated on the Senate floor between now and Memorial Day.

I do apologize to members and to witnesses for the length of time we are putting into this, but I think it is a good thing because this is so important.

I know that the present panelists have been questioned by Senator Tsongas, but they have not yet had a chance to give their opening statements.

We ask that those statements be summarized, but since this is such an important subject, we do not want to leave anything unsaid.

I will call first Ambassador Robert Buchheim, who was the U.S. Representative to the 1978 and 1979 United States-Soviet Union ASAT talks. He was probably there when the United States and Soviet Union broke off those talks.

We also have on our panel Dr. Sidney Drell, deputy director of the Stanford Linear Accelerator, and Professor Albert Carnesale of Harvard University.

First I will call upon Ambassador Buchheim to give his statement.

STATEMENT OF HON. ROBERT W. BUCHHEIM, U.S. REPRESENTATIVE TO THE 1978-79 UNITED STATES-SOVIET UNION ASAT TALKS, PHOENIX, ARIZ. (Resumed)

Ambassador BUCHHEIM. Thank you, Mr. Chairman.

In Senator Percy's letter to me inviting me to come here, he expressed a particular interest in my judgment as to progress made in the ASAT negotiations, which I led, and an assessment of the potential now for successful negotiations to limit or ban ASAT's and other space-based and space-directed weapons, the significance of the Soviet draft treaty, and the administration's March 31 report on ASAT arms control.

As to his first question, I will repeat verbatim what I said on March 12, 1984, at a symposium in The Hague: "What about the U.S.-U.S.S.R. negotiations of 1978 and 1979?" The discussions in 1978 and 1979 were serious and open and both sides were learning, a matter of the utmost importance. Both sides brought in a

common position, that is, that the talks would be held in confidence; and that common position stands today.

I will, therefore, not go much beyond two points. First, the structure of the subject comes down to this: agreement on violent acts that will not be carried out against space objects, limitations on testing of means for doing such violent acts, and provisions to limit or prohibit possession of means for doing violence to space objects. Second—and I am now speaking of more than a month ago—I will, to the extent that I can within the existing understanding as to confidentiality, answer questions you might have.

At the time I said that Boris Mayorski was present. He was on the Soviet side of the table during the 1978–79 talks, and he joined me in answering questions.

What I said in The Hague 6 weeks ago I stand by today, except that Mr. Mayorski is not here today.

I am aware of the constraints on any person or institution having an involvement with U.S. foreign policy; however, somebody, somehow, on the U.S. side ought to be talking now with the Soviet side about ASAT matters.

Conversations in the Committee on Disarmament [CD] are appropriate and important, but they are no substitute for bilateral United States-Soviet dealings.

This is not a question of alternatives; it is a question of combinations. There does need to be widely held agreeement on space arms control; but such widely held agreement must include agreement between the United States and the Union of Soviet Socialist Republics. The report, dated March 31, of the U.S. administration, endorsed the important work of the CD, and I applaud that; but I do not understand or applaud the absence of United States-Soviet talks.

In my statement in The Hague on March 12, I also said, "I am in favor of an early antisatellite agreement. Why do we not have one now? During bilateral U.S.-U.S.S.R. negotiations" in 1978 and 1979 "we came rather close to one; then the whole enterprise went into a suspended state because of U.S. domestic political developments, entry of the Soviet Union into Afghanistan, and other difficulties on the international scene."

"In my opinion, this suspension should not have happened, but it did."

"Those bilateral efforts should be resumed at the earliest possible time."

I stand by those views today, with particular emphasis on the importance of resumption of bilateral negotiations. The suspension of the negotiations of 1979 should not have happened.

Mr. Chairman, I add a personal expression of opinion that your committee would do a vital service to our country by seeking effective ways to interdict any more appeal to petulance in the place of policy.

Senator PRESSLER. I did not quite understand that. Would you say that sentence again?

Ambassador BUCHHEIM. Yes.

In my opinion, your committee would do a vital service to our country by seeking effective ways to interdict more appeals to petulance than to policy in our dealings with the Soviet Union.

Desirable negotiations on topic A ought not be terminated because of problem B. Linkage, which means many things to many people, will never go away. But it ought not get carried to the point of impractical national rejection of the plain fact that the U.S.S.R., like its political predecessors and unpredictable successors will not just vanish from this Earth under circumstances of our choosing.

Anyone who wants to claim a formula for training a big bear ought to have to start by meeting one, and then have been seen in verified successful action with one.

Enough said.

The bear and his inevitability on Earth are fundamental to the questions of your committee and to the administration report of March 31, in which it is properly said, and I quote, "ASAT arms control appears to span a greater breadth of subjects than any other areas of arms control."

This is fundamental to the planning, programing, organizing and operating of military establishments, ours and the bear's.

I have no enduring reliable answers to the many questions raised by today's space activities; and I do not think anyone else has all of those answers. However, we have taken a step forward in the process by establishing the Space Command, which is charged with thinking through such matters and managing space programs.

I presume to remind you that modern arms control flowed mainly from three sources: (a) the influence of Trevor Gardner, Assistant Secretary of the Air Force; (b) the influence of John McCloy, whose qualifications need no elaboration; and (c) technological facts as to what might be done using satellites.

In my opinion, our national interests would be served by more continued attention to these three legs of the arms control stool, which today, operationally, I would put this way. First is more direct involvement of our military service departments—not the Department of Defense, but the military service departments—in matters of arms control. Second is more careful and practical attention to arrangements in other organizations, not excluding the military service departments, devised by John McCloy, along with Trevor Gardner, of the U.S. Arms Control and Disarmament Agency, which I note is not represented here today. Third is, keep close to the technology and how it might evolve, and continue our efforts to understand how these matters might appear to the eternal bear who has no need to love us.

I mention these origins because I agree with and take seriously the observations in the administration's report about the widely ramified nature of the subject. I think we are again at a historic turning point.

A big step was accomplished when we struck a deal with the bear a dozen years ago to leave unthreatened the satellite instruments used to make a reality of President Eisenhower's aspiration for an "open skies" regime. The strategic forces of all concerned have come to live with that stabilizing regime. In my opinion, we ought not prejudice that vital regime through antisatellite schemes of either side.

The historic turning point we face now is what to do about the implications of an "open skies" space regime for tactical forces, including the surface Navy—a matter discussed at some length, and

with emphasis, in the administration's report of March 31. This problem has been in view for many years, more than 10.

The productive reply to this circumstance, which will never again go away, is not an appeal to ASAT but a major rethinking of equipment, deployment and operating tactics of the surface forces affected.

I addressed this matter in my remarks in The Hague in March and in more detail in testimony on April 12 before the Senate Armed Services Committee. My views have not changed. What is needed is dealing with a professional military task of enduring importance.

Mr. Chairman, with your permission, I would like to hand the text of the statement at The Hague that I referred to up to you to be included in the record.

[The information referred to follows:]

ANTISATELLITE WEAPONS, AND SOME RELATED MATTERS

(By Robert W. Buchheim)

(Prepared Remarks Before a Symposium on Conditions Essential for Maintaining Outer Space for Peaceful Uses, Sponsored by the United Nations University and The International Institute of Space Law of The International Astronautical Federation; Peace Palace, The Hague.)

Ladies and Gentlemen: Thank you for inviting me to visit with you about the developing legal regime for regulation of activities in outer space. This is a subject which has been of interest and concern to me for a long time.[1,2,3,4,5] It must be a matter of concern for all of us for a very long time. Man is not going to go space-faring once and then just come home to stay; but Earth is our home, and we need to preserve it as our home.

Before going too far, I must mention that I am not an official of the U.S. Government and cannot speak for that Government.

The International Astronautical Federation has always been pointed toward the long-term future. It should continue to be pointed toward the future, and, in the process, should continue to be pointed toward the preservation of our home. A part of that preservation effort is of a legal nature; but not entirely. At the same time, I agree with the observations of Neill Hosenball [6] who suggests that the development of law as to space activities ought not to "get ahead of itself" just for the sake of making law; but, rather, should stick closely to practical facts as they evolve—not too soon; not too late. This is a counsel of perfection, but a sound one; change is to be expected but cannot be predicted in detail, and, in many ways, cannot be stopped. Basic premises of this symposium, as I understand it, are that practical facts are changing rapidly and that, accordingly, further legal measures are needed. The Guidelines for this symposium point out that we must face explicitly the question "what is the problem to be solved" in setting up new legal measures.

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[1] Robert W. Buchheim and the Staff of the Rand Corporation; *"Space Handbook, Astronautics and Its Applications"*; Random House, 1958 (prepared at the request of the Select Committee on Astronautics and Space Exploration, U.S. Congress).

[2] Robert W. Buchheim; "Activities in Space: A Matter for International Regulation"; Vital Issues; (a service of the Center for Information on America; Washington, Connecticut; vol. XXXII, No. 5) January 1983.

[3] "Arms Control and the Militarization of Space" Hearings before the Subcommittee on Arms Control, Oceans, International Operations and Environment of the Committee on Foreign Relations, U.S. Senate; 97th Congress, 2d session, on S. Res. 129, expressing the Sense of the Senate with respect to resumption of negotiations between the United States and the Union of Soviet Socialist Republics on the limitation of antisatellite (ASAT) weapons systems; 99-711-0; U.S. Government Printing Office; Sept. 20, 1982.

[4] Robert W. Buchheim; "Treaty Making and Verification"; Spectrum; The Institute of Electrical and Electronics Engineers; October 1982; p. 105.

[5] Robert W. Buchheim; "Minimizing the Misuse of Space"; Spectrum; The Institute of Electrical and Electronics Engineers; September 1983; p. 38.

[6] S. Neill Hosenball; "Who Owns What? Earth Law for Space"; Spectrum; The Institute for Electrical and Electronics Engineers; September 1983; p. 76.

We are dealing here with a difficult and dynamic subject. In my opinion it will not be possible to deal with this subject effectively by searching for "definitions," except in a few special instances. What is needed is clarity as to facts and purposes, as noted in the Guidelines for this symposium.

Now, having said something about definitions that might seem to some to be unpleasant, I will pause to say something nice and also important. Returning to the International Astronautical Federation, my being invited to be here with you reminded me of the first IAF annual conference I attended. It was held in Rome, in 1956. It was my privilege to present to that conference a paper on Artificial Satellites of the Moon,[7] then viewed by many as a rather remote subject, but experienced just about a dozen years later by Apollo astronauts as a quite practical activity. Well, the high point of this recollection is that the IAF meeting of 1956 included an audience with the Pope at Castel Gandolfo, where I also had the interesting experience of meeting Mr. Sedov, then a prominent official in the space program of the U.S.S.R. The Pope made a brief address, which was a model of simplicity and sound commentary—His Holiness did not seem to need any appeal to definitions to say what he meant to say, that is, that space activities should be encouraged and pursued to the general benefit of mankind. Sedov and I knew even then that serving that purpose would not involve forbidding acts by people in military uniforms—regulated, yes, partly; forbidden, no.

Spacecraft, in many forms, serve quite desirable and stabilizing functions of an essentially military nature; probably the most important being collection of objective intelligence information to guard against surprise—indeed, against unwise reactions in panic—to support verification of compliance with arms control agreements and to suppress excessive military build-ups flowing from simple ignorance or wide ranges of uncertainty about forces of others. Space objects to serve these purposes can be at risk from anti-satellite weapons. Space objects are also now used in routine—and not so routine—ways to support and amplify the effectiveness of terrestrial military forces, with reconnaisance information, communications, meteorologic data, and so on. It is in this area that most motivation is to be found for wanting anti-satellite systems. No responsible national military establishment or alliance system—can simply ignore a potential opponent in possession of space assets for targeting or otherwise enhancing the effectiveness of its terrestrial forces. And it is precisely here that the critical choice lies, to be made by governments in the broad sense: is it better to posses and promote means for doing violence to space objects in readiness to suppress astronautical support to terrestrial forces or is it better to live with this practical problem—and make military adjustments as wit and will can enable—by putting into place effective agreed limitations on anti-satellite capacities and activities? In my personal opinion, the latter would be the better choice. To put it simply, President Eisenhower's goal of a regime of "open skies" is here, thanks to astronautical technology, and represents an asset for such strategic purposes as guarding against surprise attack and needless weapon build-ups and promotion of arms control. That is far more important than catering to the tactical convenience of being ready to poke out the eye of a radar satellite that might occasionally see a ship. Indeed, if such radar satellites become an unbearable nuisance, why not construct an agreement to prohibit them? In short, tactical forces need to evolve in ways which are based on acceptance that they must operate under an "open-skies" environment if the strategic value of "open skies" is to be preserved.

I am in favor of an early anti-satellite agreement. Why do we not have one now? During bilateral U.S.-U.S.S.R. negotiations we came rather close to one; then the whole enterprise went into a suspended state because of U.S. domestic political developments and the entry of the Soviet Union into Afghanistan and other difficulties on the international scene. In my opinion, this suspension should not have happened; but it did—this is not the only instance of an event that I found out of harmony with my personal views. Again in my opinion, those bilateral efforts should be resumed at the earliest possible time.

What about draft text for an anti-satellite agreement? With all respect, I am not in sympathy with non-governmental efforts to construct and float such texts. I argued this view with friends who worked on the report of the Union of Concerned Scientists,[8] urging them instead to prepare an illuminating report on the substance

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[7] Robert W. Buchheim; "Artificial Satellites of the Moon"; Associazione Italiana Razzi, Proceedings of the VII International Astronautical Congress; Rome; Sept. 17-22, 1956.

[8] *"Anti-Satellite Weapons: Arms Control or Arms Race?;"* Union of Concerned Scientists; Cambridge, Mass.; June 30, 1983.

of the matter. They took half of my advice, and they wrote a very good essay on substance; but they were not inclined to give up their text-drafting. Why do I not fancy text-drafting? Setting aside details, if I were again to be sent off by my Government to negotiate on this subject, I would not want to be burdened by the existence of such a text, based on no clear government authority and devoid of any negotiating record based on careful discussion with the other side, not to mention agreements on substance between the sides. A unilateral draft submitted by a non-government organization is only that: a unilateral draft of a non-governmental organization, representing no agreement on substance but likely to prejudice the position of the side whose private citizens prepared that draft. I have absolutely no expectation of being sent off to negotiate on anti-satellite matters and surely have no notion as to how the Government of the U.S.S.R. might go about a hypothetical negotiation; but please bear in mind the prejudicial potential of a text, as well as its possible constructive features, when you move toward your conclusions.

What about the U.S.-U.S.S.R. negotiations of 1978 and 1979? Some of the documentation circulated before this symposium carried an expression of interest in the positions of the two sides during those discussions. The discussions were serious and open, and as I think is usual in serious talks, both sides were learning—a matter of the utmost importance. Both sides brought in a first common position, that is, that the talks would be held in confidence; that common position stands today. I will, therefore, not go much beyond two points—first, the structure of the subject comes down to: agreement on violent acts that will not be carried out against space objects, limitations on testing of means for doing violence to space objects, and provisions to limit or prohibit possession of means for doing violence to space objects; and second, I will, to the extent I can within the existing understanding as to confidentiality, answer questions you might have. Boris Mayorski is here; he was on the Soviet side of the table during 1978–1979 talks, and I would hope that he could join me in replying to your questions.

In my opinion, the critical question to deal with in considering the drafting of an international agreement on anti-satellite matters is that of scope: I think a general anti-satellite agreement dealing with actions, or means for such actions, against space objects—and only space objects—is both desirable and possible [3]; I think that a general agreement as to actions, and means for such actions, to influence the carrying out of functions through systems using space objects as components can only be dealt with through ad hoc agreements such as the SALT provisions concerning the verification function or the International Telecommunications Convention as to the communications function.[3] I will not try to amplify much on this matter just now, but I would be happy to deal with it further if you care to do so during the discussion period.

The outlines of a simple example would be as follows: suppose A wants to try to gather information about military radio emitters of B, and chooses to make this attempt by putting into orbit a satellite which is equipped to pick up radiofrequency fields in its vicinity and then do whatever its master, A, has programed it to do—which might include repeat transmissions to ground stations of A. The functions of the space object are to detect radiofrequency fields in its vicinity and transmit to ground stations information in accordance with its programing—a party to general anti-satellite agreement might very reasonably undertake not to do violence to the space object. It is, however, unlikely to the point of utter implausibility that any country B would undertake, in an anti-satellite agreement to, in effect, guarantee the free carrying out of the intelligence-collection of the system (made up of the space object plus various kinds of ground facilities and other components)—such an undertaking would involve abandonment of such elementary rights as the right to turn off some of its radio emitters as it might choose.

Now a few positive remarks on definitions. The Guidelines paper for this symposium mentioned a need for a definition of "weapons of mass destruction." There is such a definition. My files did not cough it up in time for this trip, but it exists, from the late 1940's if I recall correctly. It began in a fairly obscure UNGA report on conventional weapons, in which conventional weapons were taken to be weapons other than weapons of mass destruction. There, weapons of mass destruction were defined as nuclear explosive weapons, radiological materials weapons, biological weapons, chemical weapons, and any new weapons created in the future that would have comparable destructive effects. This definition again came into view when discussions began in the CCD on possible new types of weapons of mass destruction, and was generally acknowledged by participants. It was again referred to in the Letter of August 11, 1981, sent to the United Nations General Assembly by Foreign

Minister Gromyko Concerning a Prohibition on the Stationing of Weapons of Any Kind in Outer Space.[9]

There are too many individual topics to try to get into hardly any in detail, but I do want to mention a few:

1. Arms race in space—what? Judge Lachs mentioned space-based ABM directed at offensive deterrent missiles. Such a development would have implications for ASAT; but their likely nature is still rather opaque. What else? Reconnaissance satellites and satellites to use in control of terrestrial forces are of a military nature but seem desirable and should not be held liable to attack. Some more clear description of the "arms race" idea is needed. This point is noted in the Guidelines for this symposium.

2. The Guidelines also note the need to give attention to hazards to space objects from sources other than weapons. In my opinion, this need is now greatest as to satellites in geosynchronous orbit. Crowding of this uniquely important orbit region is a real prospect, with attendant prospects for accidents and other problems. The International Telecommunications Convention is the proper legal vehicle for dealing with frequencies, powers, antenna characteristics, etc., but more could be done. Examples might be agreed prohibition on explosive extirpation of exhausted satellites, undertakings to hold to a minimum any unnecessary separation into several parts of objects placed in geosynchronous space, undertakings to equip satellites emplaced in geosynchronous space so they can be dispatched out of geosynchronous space when no longer useful, undertakings to co-operate in developing such anticlutter means.

3. There is no proximate need for drawing an arbitrary line to separate jurisdically air space from outer space.

4. There are some unnecessary flaws in the Registration Convention. For example, it refers to "a space object" (singular) through reference to a launch (singular); however, with rare exceptions, a typical launch will place into outer space more than one object—perhaps 5, 10, 20 or more, all on separate trajectories which cannot be described by any single set of orbit parameters mentioned in the Convention. The paramenters reported to the UN Registry seem to be based on orbits of "active" objects, but this is not sufficient in an era of dormant objects which can be activated later—for example communication satellites "stored in orbit" for rapid activation or non-emitting "space mine" weapons. The registration process is too slow to be of interest with respect to limitations on weapons in space.

5. The Soviet anti-satellite interceptor of current type does go into orbit, so presumably it should be registered when tested. The US anti-satellite interceptor of current type will not go into orbit.

6. Perhaps the Registration Convention could be augmented by an agreement that the Parties will inform one another of the locations of their national registries and description of procedures for examining national registries.

7. An important strengthening of the outer space legal régime occurred in December 1983 when the People's Republic of China became a Party to the Outer Space Treaty.

Ambassador BUCHHEIM. What do I have to say about strategic defense? Not much. I am in favor of exploring it seriously and in depth. I would not be in favor of a military program founded on a premise of success, certainly not a premise of success on some date certain.

There is another way to render long-range ballistic missiles impotent and obsolete, and that is by agreement, as soon as possible, to just eliminate them entirely. Then a strategic defense would need only deal with the small numbers of missiles that might be held in a clandestine way. This might seem like a remote negotiating objective; however, there is an old truth among gamblers: You can't win if you don't try.

[9] Letter dated Aug. 10, 1981 from the Minister for Foreign Affairs of the Union of Soviet Socialist Republics addressed to the Secretary-General; "Request for the Inclusion of a Supplementary Item in the Agenda of Thirty-sixth Session: Conclusion of a Treaty on the Prohibition of the Stationing of Weapons of Any Kind in Outer Space"; A/36/192, Aug. 11, 1981; United Nations General Assembly, Thirty-sixth Session.

What about the significance of the Soviet draft treaty? In my opinion, it has no significance except Soviet recognition of the widely held view that something in the way of space arms control agreement is needed. I do not believe the Soviet draft would make much difference one way or another in specific bilateral negotiations.

In my opinion, a truly vital element in crafting an ASAT agreement is that of scope. I addressed this matter in some detail in testimony before your Arms Control Subcommittee, sir, on September 20, 1982. I remain convinced that understanding on scope is the essence of the matter.

Let me say a few more words on the administration's report of March 31: One positive and of very great importance and a second one of minor importance.

The positive point is this: The administration's report includes the observation that negotiations between the United States and the U.S.S.R. on control of antisatellite weapons were held in 1978 and 1979: That those talks involved an extensive discussion of some of the problems of space arms control, and revealed major differences between the two sides.

Now, I don't really care about the use of the word "major." What I do care about is the word "revealed," because this seems to me to be in harmony with what I said in The Hague in March, that is, that in the 1978–79 talks, both sides were learning, a matter of the utmost significance.

Negotiating is a learning process. Anyone who thinks he has it all figured out in advance is bound to fail.

The other side will have good ideas, and also some poor ones. So will we. The essential learning process cannot be carried out by either side all by itself.

As to my minor negative comment on the administration's report of March 31, I think the arguments about residual ASAT capabilities are much overdone. Only a real nut, or someone under extreme provocation, would shoot himself in the foot by setting off a nuclear explosion in space. Use of a ballistic missile as an ASAT instrument would not be so simple as is implied by the report's phrase "with modified guidance logic." The problem is bigger than that.

Concern about "electronic countermeasures of sufficient power to damage satellite functions" was operationally solved in the early days of radio. It was then called "automatic volume control" and it is now routine.

Finally, an optimistic note: A substantial aberration in the international legal regime was removed when the People's Republic of China became a party to the Outer Space Treaty in December 1983.

I would like to add an informal remark about something that has become a bit of an obsession with me. We have heard it again today. It concerns shooting down satellites.

An unhappy fact of physics is that if you shoot at a satellite and even if you hit it, it will not come down. It will stay up there and go its merry way Newtonia leaving the shooter with the puzzle, "What have I accomplished?"

It is a big problem. With an air defense system, if you shoot at an airplane and hit it, it crashes. You know what you have accom-

plished. Not in the case of a satellite. The damage assessment task is a big part of the problem.

Thank you, sir.

[Ambassador Buchheim's prepared statement follows:]

PREPARED STATEMENT OF HON. ROBERT W. BUCHHEIM

Mr. Chairman, it is a pleasant honor to be invited to appear before you and your Committee on very important forward-looking matters.

In your letter of invitation [1] you expressed a particular interest in—and I quote—"your judgment as to progress made in the ASAT negotiations you led and your assessment of the potential now for successful negotiations to limit or ban ASAT's and other space-based and space-directed weapons; the significance of the Soviet draft treaty; and, the Administration's March 31, 1984, report on ASAT arms control."

As to your first question, Mr. Chairman, I will repeat, verbatim, what I said on the subject of space arms control on March 12, 1984, at a symposium in The Hague (full text provided for the record): [2] "What about the U.S.-U.S.S.R. negotiations of 1978 and 1979? . . . The discussions were serious and open, and as I think is usual in serious talks, both sides were learning—a matter of the utmost importance. Both sides brought in a first common position, that is, that the talks would be held in confidence; that common position stands today. I will, therefore, not go much beyond two points—first, the structure of the subject comes down to: agreement on violent acts that will not be carried out against space objects, limitations on testing of means for doing violence to space objects, and provisions to limit or prohibit possession of means for doing violence to space objects; and second, I will, to the extent I can within the existing understanding as to confidentiality, answer questions you might have. Boris Mayorski is here; he was on the Soviet side of the table during 1978–79 talks, and I hope that he would join me in replying to your questions."

What I said in The Hague 6 weeks ago I stand by today, except that Mr. Mayorski is not here today as he was then and there.

I am fully aware of the constraints on any person or institution having an involvement with U.S. foreign policy; however, it seems to me that somebody, somehow, on the U.S. side, ought to be talking now with the Soviet side about the ASAT matter. Conversations in the Committee on Disarmament are appropriate and important, but they are, in my opinion, no substantial substitute for essential bilateral U.S.-U.S.S.R. dealings. This is not a question of alternatives; it is a question of combinations. There does need to be a widely-held agreement on space arms control; but such widely-held agreement must include agreement between the United States and the U.S.S.R. The report,[3] dated March 31, 1984, of the U.S. Administration, endorsed the important work of the CD, and I applaud that, but I do not applaud the seeming absence of the essential bilateral U.S.-U.S.S.R. talks.

As a part of my statement in The Hague on March 12, 1984, I also said—and again I quote myself—"I am in favor of an early anti-satellite agreement. Why do we not have one now? During bilateral U.S.-U.S.S.R. negotiations we came rather close to one; then the whole enterprise went into a suspended state because of U.S. domestic political developments, the entry of the Soviet Union into Afghanistan, and other difficulties on the international scene. In my opinion, this suspension should not have happened; but it did—this is not the only instance of an event that I found out of harmony with my personal views. Again in my opinion, those bilateral efforts should be resumed at the earliest possible time". I stand by those views today, with particular emphasis on the importance of resumption of bilateral U.S.-U.S.S.R. negotiations; the suspension of negotiations in 1979 should not have happened. In the context of these hearings, Mr. Chairman, I add the personal expression of opinion that your Committee would do a vital service to our country by seeking more effective ways to interdict any practice of petulance in the place of policy in our dealings with the U.S.S.R., to try to ensure that desirable negotiations on topic A are not terminated just because of problem B—"linkage," which means many things to many people, will never go away, but it ought not get carried to the point of impractical and hopeless national rejection of the plain fact that the

[1] Letter; Charles H. Percy to Robert W. Buchheim; Apr. 11, 1984.

[2] Robert W. Buchheim; "Anti-Satellite Weapons, and Some Related Matters"; (Prepared remarks before a symposium on Conditions Essential for Maintaining Outer Space for Peaceful Uses, sponsored by the United Nations University and The International Institute of Space Law of The International Astronautical Federation; Peace Palace, The Hague.) Mar. 12, 1984.

[3] "Report to the Congress, U.S. Policy on ASAT Arms Control"; attachment to letter from President Reagan to Hon. George Bush, President of the Senate; Mar. 31, 1984.

U.S.S.R., like its political predecessors and unpredictable successors will not just vanish from this Earth under circumstances of our choosing. Anyone who wants to claim a formula for training a big bear ought to have to start by meeting one and then have been seen in verified successful action with one. Enough said. The big bear is there; what do we want to do?

I mention the bear and his inevitability on Earth because these circumstances are fundamental to the questions of your Committee, and to the Administration report of March 31, 1984, in which it is properly said that—I quote—"ASAT arms control appears to span a greater breadth of subjects than any other areas of arms control." [3] They are fundamental to the planning, programming, organizing and operating of military establishments, ours and the bear's. I have no enduring reliable answers to the many questions raised by modern circumstances of space activities; and, in all immodesty, I do not think anyone else has all of such answers; however, we have taken a step forward in the process by establishing the Space Command which is charged with the important task of thinking through such matters and managing space programs as elements of United States and other national security interests. It is an urgent current task. I presume to remind you that modern arms control flowed mainly from three sources; (a) the influence of Trevor Gardner, Assistant Secretary of the Air Force; (b) the influence of John McCloy, a man whose qualifications need no elaboration; and (c) the practical technological facts as to photography through satellites. In my opinion, our national and international security interests would be well served by more and continued attention to the essence of those three legs of the arms control stool, which today, operationally, I put this way: first, more direct involvement of our military service departments—not the Department of Defense, the military service departments—in matters of arms control; resume, in effect, the work of Trevor Gardner; second, more careful and practical attention to the role of arrangements in the field of arms control, as carried out between governments through elements other than but not excluding the military service departments; in practice this means use of the unique potentialities, devised by Mr. McCloy along with Trevor Gardner, of the U.S. Arms Control and Disarmament Agency, and first implemented by William Foster; third, keep close to the facts of technology and how they might evolve—other witnesses will speak to this subject; we also need to continue our efforts to understand how these matters might appear to the bear, who has no need to love us.

I mention historical origins because I agree with and take seriously the observations in the Administration's report about the widely-ramified nature of the subject; I think we are again at a historic turning point.

A big step was accomplished when we struck a deal with the bear a dozen years ago to leave unthreatened the satellite instruments used to make a reality of President Eisenhower's aspiration for an "open skies" regime. The strategic forces of all concerned have come to live with that stabilizing regime; in my opinion, we ought not prejudice that vital regime through anti-satellite schemes of either side.

The historic turning point we face now, in my opinion, is what to do about the implications of an "open skies" space regime for tactical forces, particularly the surface Navy—a matter discussed at some length, and with emphasis, in the administration's report of March 31, 1984. This problem has been in view for many years—more than 10. In my opinion, the productive reply to this circumstance, which will never go away, is not an appeal to ASAT but a major rethinking of equipment, deployment and operating tactics of the surface forces affected. I addressed this important matter in my remarks in The Hague in March,[2] and, in more detail, in testimony on April 12, 1984, before the Senate Armed Services Committee.[4] My views have not changed; what is needed is dealing with a professional military task of enduring importance.

What do I have to say about strategic defense? Not much; I am in favor of exploring it seriously and in depth; I would not be in favor of a military program founded on a premise of success, certainly not a premise of success on some date certain. There is another way to render long-range ballistic missiles impotent and obsolete—by agreement to eliminate them entirely; then a strategic defense need only deal with the small numbers of missiles that might be held in a clandestine way. This might seem like a remote negotiating objective; however, there is an old truth among gamblers: you can't win if you don't try.

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[4] Robert W. Buchheim; "Military Space Activities, Arms Control, and Military Preparations"; statement before the Senate Armed Services Committee, room 22, Senate Office Building; Apr. 12, 1984.

space arms control agreement is needed; I do not believe the Soviet draft would make much difference one way or another in specific bilateral negotiations.

In my opinion, a truly vital element in crafting an ASAT agreement is that of scope. I addressed this matter in some detail in testimony before the Arms Control Subcommittee of this committee on September 20, 1982.[5] I remain convinced that understanding on scope is of the essence of the matter.

A few more words as to the Administration's report of March 31, 1984; one positive and, in my opinion, of very great importance; and a second of rather minor importance. The positive one: the administration's report includes the observation—and I quote—". . . negotiations between the United States and U.S.S.R. on control of anti-satellite weapons were held in 1978-79. These talks involved an extensive discussion of some of the problems of space arms control, and revealed major differences between the two sides." [3] I really do not care about the use of the word "major"; what I do care about is the word "revealed," because this seems to me to be in harmony with what I said in The Hague on March 12, 1984, that is, that in the 1978-79 talks, "both sides were learning—a matter of the utmost significance." [2] Negotiating is a learning process; anyone who thinks he has it all figured out in advance is bound to fail. The other side will have good ideas, also some poor ones; so will we. The essential learning process cannot be carried out by either side all by itself.

As to my minor negative comment on the administration's report of March 31, 1984: in my opinion, the arguments about residual ASAT capabilities are overdone: only a real nut, or someone under extreme provocation, would shoot himself in the foot by setting off a nuclear explosion in space; use of a ballistic missile as an ASAT instrument would not be so simple as is implied by the phrase "with modified guidance logic"; concern about "electronic countermeasures of sufficient power to damage . . . satellite functions" was operationally solved in the early days of radio—it was then called Automatic Volume Control, and it is now routine.

Finally, an optimistic note: a substantial aberration in the international legal regime was removed when the Peoples Republic of China became a party to the Outer Space Treaty in December 1983.

Senator PRESSLER. Thank you, Ambassador Buchheim.
Dr. Drell.

STATEMENT OF SIDNEY D. DRELL, DEPUTY DIRECTOR, STANFORD LINEAR ACCELERATOR, STANFORD, CALIF. (Resumed)

Dr. DRELL. Thank you, Mr. Chairman, for the opportunity to testify on this vital and timely subject.

In my statement, I will first address the issues raised by the President's Defense Initiative, which challenges the most basic premises of the United States-Soviet strategic relationship, and then ASAT, which is tightly coupled to our ABM activities, both in technology and policy.

President Reagan's call for a shift from deterrence based on the mutual fear of nuclear retaliation to reliance on defense against nuclear annihilation had strong moral appeal. It also raises once again two critical questions that we have faced since the advent of nuclear weapons and the development of intercontinental ballistic missiles more than 20 years ago. One, is it realistic on technical grounds for us to build an effective ABM shield to protect us from nuclear annihiliation. And, two, how will an intensified effort to develop ABM's change the basic United States-Soviet strategic relationship and affect U.S. security and the likelihood of nuclear war.

Our last national debate on these issues occurred 15 years ago and led to the acceptance by the United States and the Soviet

[5] "Arms Control and the Militarization of Space"; Hearing before the Subcommittee on Arms Control, Oceans International Operations and Environment of the Committee on Foreign Relations, U.S. Senate; 97th Congress, 2d session, on S. Res. 129; Sept. 20, 1982; Committee Print 99-711 O.

Union of the very severe limitations on ABM negotiated at SALT in 1972.

This did not reflect any lack of awareness of strategic defense and the arguments for it. Rather, it was a pragmatic conclusion.

In the 1970's, each of the superpowers judged the deployment of a nationwide defense, in sum, to be futile on technical grounds, destabilizing to the strategic balance, and very costly.

Now, in 1984, has anything happened to alter that prior judgment?

There have indeed been tremendous advances in recent years in the technology pertinent to this problem, including the ability to produce powerful directed energy beams and to handle vast quantities of data that have removed some of the shortcomings of previous defense concepts.

But I have concluded, based on long experience and recent, intense work on this problem, that we do not now know how to build an effective nationwide defense, nor is there any prospect of achieving one in the foreseeable future unless the offensive threat is first tightly constrained technically and greatly reduced numerically as a result of major progress in arms control.

I agree with Dr. Richard Delauer, the Under Secretary of Defense for Research and Engineering, who said, "With unconstrained proliferation, no defensive system will work."

The difficulties faced by a defense are not technological alone. Even if the very ambitious and costly R&D program recently proposed by the administration achieves all of its major goals, far beyond presently demonstrated technologies, great operational barriers will still remain. This is a key point.

Let me illustrate by considering a system for attacking and destroying missiles during their boost phase while their engines are still burning for the first few minutes after launch and before the many individual warheads and decoys are deployed, the first of the five layers that General Abrahamson mentioned this morning.

An effective boost phase ABM which greatly reduces the number of objects that subsequent layers of a defense must destroy is crucial to a nationwide defense. It can be based in space or it can be based on the ground.

The most serious problem for a space-based system is its extreme vulnerability to direct attack. Space stations can be destroyed by relatively cheap space mines placed in nearby orbits and detonated by radio command from the ground. Additional operational problems include cost and inefficiency.

For example, individual laser satellites circling the Earth will be on station, over launch areas of Soviet ICBM's only a small fraction of the time, and therefore hundreds will have to be put into orbit for continual coverage.

In addition, the offense can harden his missiles against lethal effects of the laser beams.

In order to avoid the vulnerability of space basing, the battle stations may be based on ground and mounted on a missile poised to launch, that is, to pop up upon receipt of notification of enemy attack. The most promising popup system of this type is an X-ray laser pumped by a nuclear explosion. If this very immature technology eventually achieves what will be required for a practical

weapon, there still remains the difficult and important operational issue of whether it can be launched sufficiently rapidly even to attempt a boost phase intercept, a subject which you heard discussed this morning.

Such a popup system will have to be based far offshore, near to Soviet territory, and will have to be launched literally within seconds due to severe time constraints. Thus, the system will have to be fully automated. This includes turning over to the computers the release authority for the weapons.

But, beyond this, the offense can implement countermeasures that deny any possibility of such a popup X-ray laser defense. He can do this by redesigning his missiles to burn more rapidly and complete their boost within the atmosphere before they can even be attacked. Other technologies and systems have been proposed, but all inherit some of the drawbacks of spacebased and popup systems.

Finally, the entire system, with its many hundreds of advanced sensors and interceptors and its severe battle management requirements, would have to work to almost 100 percent perfection the first time it was used, although never fully tested under realistic conditions.

These fundamental technical and operational difficulties are implicitly recognized in the strategic defense R&D plan submitted to Congress by the Defense Department just last month. It addresses the President's goal of escaping from a reliance on deterrence, but it gives predominant emphasis to an interim goal of enhancing deterrence by deploying a defense that is only partially effective.

Whatever the goal of the ABM program, we must ask what effect the President's initiative can have on the United States-Soviet strategic relationship and our approaches to avoidance of nuclear war. On this point I find no basis for altering our conclusion at the time of our last national debate on ABM, and that is, intensified national programs in pursuit of ABM defenses are likely to prove destabilizing and therefore harmful to our security as each nation fears the purpose as well as the capability of its opponent's defenses.

It is important to recognize that the President's Strategic Defense Initiative differs significantly from the U.S. program to date, whose aim has been to be a prudent hedge against technological breakthroughs and to guard against Soviet advances and even unilateral ABM development.

The new initiative, although now just a long-term R&D program, as you heard this morning, is directed toward a Presidentially stated goal of defense that is at odds with the premises of current United States and Soviet strategic relations. Furthermore, this is a unilateral change to which the Soviet Union will have to respond in accordance with its perception of what may be the intended or actual impact on Soviet security of what the United States is doing.

Soviet adjustments in their ABM and offensive strategic programs and in their positions in the START negotiations to take account of prospective new U.S. ABM capabilities cannot be deferred until the United States makes its deployment decision 5 or 10 years hence. They will not want to lag behind our ABM programs. And in the face of a Presidential commitment to ABM which threatens their deterrent capability, will they look sympathetically at U.S.

START proposals for deep reductions in their most effective deterrent missiles and warheads?

Thus, the new defense initiative of the United States, whatever its eventual fate, is not a cost-free enterprise in strategic and arms control terms as well as economic terms. The MIRV precedent, triggered by an earlier Soviet defense initiative, is a caution to keep in mind.

Let me now turn to ASAT briefly.

It is important to recognize that ASAT is a much simpler problem than ABM defenses that operate above the atmosphere. This is because the ASAT targets are many fewer and generally more vulnerable and easier to discriminate than are those that must be destroyed by a strategic defense. Moreover, they are predictable both in their position and time, and they have communication links from Earth that can be attacked. Thus, ABM will have an ASAT capability.

The significance of ASAT for strategic defense lies in the threat it poses against the space platforms of the ABM. On the other hand, the significance of the Strategic Defense Initiative for ASAT is that it will spur technological developments that, inevitably, will be threatening to the critical communication and early warning satellite links on which a ballistic defense must rely.

This presents an unavoidable dilemma. ASAT threatens ABM, but ABM developments contribute to ASAT. Furthermore, it will be difficult, if not impossible, to distinguish R&D component testing and technology demonstrations for ABM from similar activities for ASAT. Thus, it is very likely to prove to be impractical to negotiate ASAT limitations with the Soviet Union if the Strategic Defense Initiative proceeds.

I strongly disagree with the administration's conclusion that it would not be "productive to engage in formal international negotiations" on ASAT arms control at this time, and I support Senate efforts calling for the United States to return to the negotiating table on ASAT.

Given the operational difficulties and the high energy requirements, it will be years before a practical and reliable ASAT that depends on intercept and destruction of space platforms will exist.

Now is the time, before it is too late, to start and pursue with urgency the negotiating effort to head off such threats that would be counter to U.S. interests. It is also the time to redress potential, near-term threats by improving the survivability of our satellite ground stations and by making our communication links to space more jamproof. I support Senate Joint Resolution 129, declaring "an immediate, mutual, and verifiable moratorium of limited duration on the testing in space of antisatellite weapons," and calling for immediate resumption of negotiations toward a comprehensive, verifiable treaty limiting ASAT.

In conclusion, Mr. Chairman, I see no prospect today of finding a technological fix to our perilous strategic situation with nuclear weapons. The absence of Soviet space-based and space-directed weapons, both ABM and ASAT, does a lot more for our deterrence and strategic stability than would the existence of such U.S. weapons.

While working toward a long-term goal of making nuclear weapons obsolete, we should make immediate efforts, through sensible program restraints as well as through negotiations, to keep space from being one more dimension of unnecessary weapons competition between the United States and the Soviet Union.

Thank you.

[Dr. Drell's prepared statement follows:]

PREPARED STATEMENT OF DR. SIDNEY D. DRELL

Thank you for this opportunity to appear before this committee and testify on this vital and timely subject. The President's "star wars" speech last year challenged the most basic premises of the United States-Soviet strategic relationship. It has led to the Administration's new strategic defense (ABM) initiative which deserves the most careful examination. Advances in ABM technology will inevitably contribute to advances in anti-satellite technology (ASAT) which is a much simpler technical challenge. Hence policy and restraints in both areas should be coupled to one another. In my statement I will first address the issues raised by the defense initiative; and then ASAT.

My curriculum vitae documents 25 years of substantial and continuing involvement on my part as an adviser to the U.S. Government on the strategic, arms control, and technical issues of defense and satellite systems. My statement to the Committee represents no one or organization other than my personal views.

THE STRATEGIC DEFENSE INITIATIVE: AN OVERVIEW

In his address to the nation March 23, 1983, President Reagan called for a shift from deterrence based on the mutual fear of nuclear retaliation to reliance on defense against nuclear annihilation. The impulse to look to our weapons and armed forces to defend us rather than threaten others is a natural one with strong moral appeal, and is deeply ingrained with long historical precedent in the era before nuclear weapons. However we must also look to the practical side of this issue under the shadow of current nuclear arsenals.

The President's call raises once again two critical questions that we have faced since the advent of nuclear weapons and the development of intercontinental ballistic missiles more than 20 years ago:

1. Is it realistic—on technical grounds—for us to build an effective shield (ABM) to protect us from nuclear annihilation?

2. How will an intensified effort to develop ABM's change the basic United States-Soviet strategic relationship and affect U.S. security and the likelihood of nuclear war?

Our last national debate on these issues occurred 15 years ago and led to the acceptance by the United States and the Soviet Union of the very severe limitations on ABM negotiated at SALT in 1972. This did not reflect any lack of awareness of strategic defense and the arguments for it. Rather it was a pragmatic conclusion. Whatever the thoretical desirability of ABM defenses as opposed to deterrence based on assured destruction, in the 1970's each of the superpowers judged the deployment of a nationwide ABM shield, in sum, to be futile on technical grounds, destabilizing to the strategic balance, and very costly.

As the question of strategic defense is now reopened in 1984, has anything happened to alter that prior judgment?

There have indeed been tremendous advances in recent years in the technology pertinent to this problem that have removed some of the shortcomings of previous defense concepts. These include producing directed energy beams of high power that travel as accurate bullets at the speed of light, and more efficient gathering, processing and transmitting of vast quantities of data for the purpose of battle management. There have also been major improvements in the offensive forces. I have concluded, based on long experience and recent intense work on this problem, that we do not now know how to build an effective nationwide defense, nor is there any prospect of achieving one in the foreseeable future, unless the offensive threat is first tightly constrained technically and greatly reduced numerically as a result of major progress in arms control. I agree with Dr. Richard DeLauer, Under Secretary

of Defense for Research and Engineering, who has said,[1] "With unconstrained proliferation, no defensive system will work."

The major technical fact that has not changed with time is the overwhelming destructive power of nuclear weapons. To speak, as President Reagan did, of rendering nuclear weapons "impotent and obsolete" by defending one's vital national interests—people, industries, cities—against a massive nuclear attack still requires a defense that is almost perfect. Technical assessments of ABM concepts cannot escape this awesome systems requirement. If but 1 percent of the approximately 8,000 nuclear warheads on the current Soviet force of land-based and sea-based ballistic missiles succeeded in penetrating a defensive shield and landed on urban targets in the United States, it would be one of the greatest disasters in all history!

Many components form a defensive system against ballistic missiles, and all are crucial to its effective operation. These include the sensors providing early warning of an attack; the communication links for conveying that information to the analysis centers for interpretation, to the command centers with authority to make decisions as to the appropriate national response, and to the military forces to implement the decisions; the sensors of the ABM that acquire, discriminate, track, point, fire and assess the effectiveness of the attack; and finally the interceptors or directed energy sources that make the kill. The systems for managing the battle and for delivering destructive energy concentrations must be operational at the initiation of an attack and must remain effective throughout. This means being on station, yet being able to survive direct attack. The ability to satisfy these two requirements simultaneously is a major operational challenge. Even if the very ambitious and costly R&D program recently proposed by the Administration achieves all of its major goals, far beyond presently demonstrated technologies, great operational barriers will still remain.

DEFENSE-IN-DEPTH

The concept of a "defense in depth" has developed since no single technology alone is adequate to provide an impenetrable defensive shield, or anti-ballistic Maginot Line. The first layer attacks the rising missiles during their boost phase while their engines are burning. Typically, this phase lasts 3 minutes for modern missiles which are powered by rockets that burn solid fuel, and up to 5 minutes for liquid fuel boosters. During this time the missile rises above the atmosphere to heights of 200 to 300 kilometers. The second (and perhaps third) layer of the defense attacks the warheads, or re-entry vehicles, as well as the post-boost vehicle (which is the small bus that aims and dispenses the individual MIRVs) during their midcourse trajectories lasting about 20-25 minutes. The final or terminal layer of the defense attacks the re-entry vehicles during the last minute or two of the flight as they re-enter the atmosphere which strips away the lighter decoys accompanying them in mid-flight. A three-layer system, each of whose layers is 90 percent effective, would allow only 8 out of an attacking force of 8,000 RVs to arrive on target and would, if achievable, be very effective, though less than perfect, as a defense.

BOOST PHASE INTERCEPT

As one looks at each layer of this defense, one encounters problems of monumental magnitude. In order to illustrate some of them I will describe the possibility of boost-phase intercept. It is the principal new element in considering ABM technologies. It also has the highest potential payoff for two reasons:

1. Whatever success is achieved in this initial layer of the defense reduces the size of the attacking force to be engaged by each subsequent layer.

2. If a missile is destroyed during boost when it is relatively vulnerable, all of its warheads and decoys are destroyed with it.

Following the missile boost phase, the defense has more time for performing its functions of acquiring and discriminating warheads from decoys, attacking its targets and confirming their destruction. On the other hand, although not so severely

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[1] As quoted in the New York Times, May 18, 1983 by Richard Halloran, for an interview with reporters on the previous day.

Dr. James C. Fletcher, Chairman of the Defensive Technologies Study Team (summer of 1983), which has been used by the Departments of Defense and Energy as the technical guidance for the Strategic Defense Initiative, testified on March 1, 1984, to the House Committee on Armed Services that "I would like to say at the outset that no one knows how effective defensive systems can be made, nor how much they might cost." The Fletcher report was concerned with defining a technology development program toward what is "conceivable" for an effective defense.

constrained by very short engagement times, it must also cope with many more objects since a single large booster is capable of deploying tens of warheads and many hundreds of decoys. Thus the two defensive layers for boost-phase and for mid-course intercept face very different technological challenges. Moreover an effective boost-phase layer which greatly reduces the number of objects that subsequent layers must analyze and attack is crucial to overall effectiveness of a defensive system.

CHEMICAL LASERS BASED IN SPACE

One of the most widely discussed systems for boost-phase intercept is a constellation of very high-powered chemical lasers and large optical systems operating to near-perfection that orbit the Earth in space. Very well focussed laser beams have the attractive feature for AMB of traveling vast distances with the speed of light in space above the atmosphere. The disadvantages of space-based lasers are that they are complex and expensive and vulnerable to direct attack; each laser platform, as it circles the Earth, will be "on station" over the launch areas of Soviet ICBMs only a small percentage of the time and therefore will have to be replicated many times over; and the offense can reduce the lethal effectiveness of the laser beams by relatively simple measures to harden his missiles. Just imagine how many lasers will have to be put into orbit. If we extrapolate the technology far beyond what has been demonstrated today to what is believed to be attainable in practice, and we assume perfect systems operation, this number come out to be in excess of 300.[2] Not surprisingly, so extensive a space-based system is very expensive—there have been published cost estimates ranging upward from $500 billion. However, the most serious problem for this or for any space-based system is its extreme vulnerability to direct attack. Most simply, the space stations can be destroyed by relatively cheap space mines placed in nearby orbits and detonated by radio command from ground. Indeed the space stations themselves are more vulnerable than the ICBMs against which they are targetted. A space-based laser system does not offer a credible prospect of an effective defensive layer.

A "POP-UP" SYSTEM OF X-RAY LASERS

In order to avoid the vulnerability of space basing, the battle-stations may be mounted on a missile based on ground poised to launch—i.e. to "pop-up"—upon receipt of notification of enemy attack. The most promising "pop-up" system of this type is an X-ray laser pumped by a nuclear explosion and designed to destroy attacking missiles during boost phase.

By itself, a nuclear explosion releases a very large amount of energy which is not focussed, but which emerges in all directions. However, if a sufficiently large fraction of the energy from the nuclear explosion can be used to drive one or more lasers, and thus be focussed into very highly collimated beams, it can cause severe impulsive damage to objects at very great distances. This technology is still very immature and improvement by many orders of magnitude in efficiency will have to be achieved before a practical weapon can be designed. I will proceed on the assumption that the necessary technology is achieved.

In considering the possibility of a practical "pop-up" system of this type, the most difficult and important operational issue to address is whether it can be launched sufficiently rapidly even to attempt a boost-phase intercept. Modern ballistic missiles complete their powered flight, or boost phase, within 3 to 5 minutes after launch. This means that the X-ray lasers have only 3-5 minutes in which to do their job. However, X-rays are absorbed by the atmosphere, and so such a defensive system must itself reach an altitude well above 100 miles within that same short time interval in order to be able to shoot at the attacking missile. Furthermore, it would have to be based far off-shore near to Soviet territory. Otherwise, due to curvature of the Earth, it will be impossible for the X-ray laser beams to "see" the booster above the horizon before the end of burn.

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[2] This analysis is contained in a recently completed report on the strategic defense initiative, now being prepared for publication, done in collaboration with Philip Farley and David Holloway at the Stanford University Center for International Security and Arms Control. The key assumptions are a laser brightness of 3.5×10^{20} watt/steradian and a booster hardness of 20 kilojoules/sq. cm. corresponding to a kill range of 1500 km. so that the lasers will be on station 5 percent of the time. The threat size is the current Soviet ICBM force of 1,400 boosters and the engagement time is 3 minutes. It will take some 300 shuttle launches just to fuel these lasers.

Since the X-ray laser will have to be launched literally within seconds due to the severe time constraints, the system will have to be fully automated. This includes turning over to computers the release authority for the weapons!

I have described formidable operational problems, but beyond these the offense can implement counter-measures that deny any possibility of such a pop-up X-ray laser defense. He can defeat this possibility of a defense by redesigning his missiles to burn more rapidly and complete their boost within the atmosphere before they can be attacked. To do so the offense will have to pay a penalty in efficiency of no more than 10-15 percent according to unclassified studies presented to the Fletcher Panel.[3]

A HYBRID SYSTEM

Other technologies and systems concepts have been proposed in an effort to escape the drawbacks of space-based and "pop-up" systems. One such concept is that of a system of ground-based lasers whose beams are aimed up to a small number of large relay mirrors at high altitudes, in or near synchronous orbits at 40,000 km altitude. These relay mirrors at high altitudes then direct the beams to various mission mirrors orbiting Earth at lower altitudes from which they are redirected on to their targets. This hybrid system has the advantage of putting fewer parts in orbit than the space-based laser system, and it also avoids the severe time constraints of a pop-up system for boost-phase intercept. On the other hand it must conquer severe technological obstacles of transmitting its light through the atmosphere without loss of focussing due to atmospheric turbulence and without loss of energy due to absorption. Even assuming these technical challenges are mastered (including developments in active optics) there still remains a serious and unavoidable operational question; i.e., the few large focussing mirrors in space are themselves a small number of high-value and expensive targets vulnerable to attack. They and the large ground-based laser stations are reminiscent of the large phased array radars of the earlier generation of ABM systems at the time of SALT I which proved to be their "Achilles heel."

Technologies other than laser beams are even less far along as candidates for ABM systems. Particle-beam technology is the least mature of the directed-energy technology efforts.

OPERATIONAL ISSUES

The data-handling—or battle management—problem is thought by many to represent the most stressing technological problem, and it is not fully understood at present.

On top of all these problems, the entire system with its many hundreds of advanced sensors and interceptors, and its severe battle management requirements, would have to work to almost 100 percent perfection the first time it was used—although never fully tested under realistic conditions in the midst of nuclear explosions!

STRATEGIC IMPLICATIONS OF THE DEFENSE INITIATIVE

These fundamental technical and operational difficulties are implicitly recognized in the strategic defense R&D plan submitted to Congress by the Defense Department last month. In addition to addressing the President's goal of escaping from a reliance on deterrence, it gives predominant emphasis to addressing the alternative, or interim, goal of enhancing deterrence by deploying a defense that is only partially effective.

Whether the goal of the ABM is to transcend deterrence or the more limited one of enhancing it, we have to ask the second critical question that I posed at the outset, of what effect the Presient's initiative can have on the heart of the United States-Soviet strategic relationship and our approaches to avoidance of nuclear war. On this point I find no basis for altering our conclusion from that of our last national debate on ABM 15 years ago. Intensified national programs in pursuit of ABM defenses can, and are likely to, prove harmful to our security as each nation fears the purpose as well as the capability of its opponent's defenses.

We may view our defenses, even though they are admittedly only partially effective, as enhancing deterrence by increasing the uncertainty of the Soviets about the potential effectiveness and success of their first strike. On the other hand, the Soviets may see our defensive programs, taken together with an ongoing intensive effort

[3] Briefings in July 1983.

to modernize and improve our offensive forces, as evidence of preparations for a first strike; a first strike that would leave them with a weakened retaliatory force against which our defenses, although imperfect, would be relatively more effective—just as a leaky umbrella is more effective against a drizzle than a downpour. Of course the same is true for the Soviet Union vis-a-vis the United States.

It is important to recognize that the President's strategic defense initiative differs significantly from the United States program to date which is a prudent "hedge" or contingency to be alert to technological break-throughs and to guard against Soviet advances and even unilateral ABM development. The new initiative as defined so far is a long-term R&D program, costing $26 billion for the first 5 years alone. While it does not specify any systems deployment, it is directed toward a Presidentially-stated goal that is at odds with the premises of current United States and Soviet strategic relations. Furthermore, at present this is a unilateral change—to which the Soviet Union will have to respond in accordance with its perception of what may be the intended or actual impact on Soviet security of what the United States is doing. Soviet adjustments in their ABM and offensive strategic programs, and in their positions in the START negotiations, to take account of prospective new U.S. ABM capabilities cannot be deferred until the United States makes its deployment decisions 5 or 10 years hence. They will not want to lag behind our ABM programs. And in the face of a Presidential commitment to ABM which threatens their deterrent capability, will they look sympathetically at U.S. START proposals for deep reductions in their most effective deterrent missiles and warheads?

Thus the new defense initiative of the United States—whatever its eventual fate—is not a cost-free enterprise, in strategic and arms control terms as well as economic terms. The MIRV precedent is a caution to keep in mind. MIRVs were originally designed to maintain, and enhance, the effectiveness of the U.S. deterrent forces in the face of the initial limited Soviet ABM deployment around Moscow and in anticipation of further system growth. However the momentum of the U.S. MIRV program continued even after the SALT I Treaty limitations on Soviet ABM removed the original argument for MIRVs. Then as the Soviets in turn deployed MIRVs, especially on their large land-based ICBMs, they became a focus of strategic instability.

SUMMARY OF ABM

To summarize: Based on technological and strategic considerations, I conclude that, if defensive systems are ever to contribute to a safer and more stable strategic relationship between the United States and the Soviet Union, they will first have to be embedded in a strict arms control regime that limits offensive systems. Technology alone will not solve the political problem of managing the strategic relationship with the Soviet Union—nor does it offer an escape from deterrence in a world heavily armed with nuclear weapons. Accelerated pursuit of ABM will give a new impulse to expansion and diversification of offensive forces. It will undermine deterrence by imperiling the ABM Treaty. Sooner or later an extensive test program will be required in order to establish confidence in the technical performance of a large and technically sophisticated defensive system. This will conflict with Article V of the ABM Treaty of SALT I which includes the statement: "Each party undertakes not to develop, test, or deploy ABM systems or components which are sea-based, air-based, space-based, or mobile land-based."

I value the ABM Treaty highly and concur with the statement in the final report to President Reagan by his Commission on Strategic Forces, dated March 21, 1984, and signed by General Brent Scowcroft, commission chairman:

"One of the most successful arms control agreements is the Anti-Ballistic Missile Treaty of 1972. . . . no move in the direction of the deployment of active defense should be made without the most careful consideration of the possible strategic and arms control implications. . . . the strategic implications of ballistic missile defense and the criticality of the ABM Treaty to further arms control agreements dictate extreme caution in proceeding to engineering development in this sensitive area."

Additionally, the United States must not let the new fascination with ABM detract us from taking important measures to assure our deterrent capability and to maintain adequate conventional strength. Crisis stability and deterrence depend pivotally on the survivability of the offensive strategic forces—which can be better assured by programs to lessen dependence on vulnerable fixed highly-MIRVd ICBMs than by defenses—and on the mutual awareness that unleashing nuclear war would be suicidal, a fact that the ABM Treaty vividly establishes. We should maintain adequate conventional strength so we need not continue to rely on our current policy of "early first use" of nuclear weapons in NATO.

LIMITATIONS ON ASAT

Turning to ASAT, it is important to recognize that ASAT is a much simpler problem than ABM defenses that operate above the atmosphere (exoatmospheric ABM). This is because the ASAT targets are much fewer and generally more vulnerable and easier to discriminate than are those that must be destroyed by a strategic defense. Moreover they are predictable both in their position and time, they are not easily replaced, and they have communication and control links up and back from earth that can be attacked. Thus any exoatmospheric ABM will have an ASAT capability.[4]

The significance of ASAT for strategic defense lies in the threat it poses against the space platforms of the ABM, in particular against the warning, acquisition and battle management sensors. On the other hand, the significance of the strategic defense initiative for ASAT is that it will spur technical developments that, inevitably, will be threatening to the critical communication and early warning satellite links on which a ballistic missile defense must rely. This presents an unavoidable dilemma: ASAT threatens ABM, but ABM developments contribute to ASAT. Furthermore it will be difficult, if not impossible, to distinguish R&D component testing and technology demonstrations for ABM from similar activities for ASAT. Thus it is very likely to prove to be impractical to negotiate ASAT limitations with the Soviet Union if the strategic defense initiative proceeds.

I strongly disagree with the Administration's conclusion [5] that it would not be "productive to engage in formal international negotiations" on ASAT arms control at this time, and I support Senate efforts calling for the United States to return to the negotiating table on ASAT. The negotiations will be tough, and U.S. concerns about verification and the potential for treaty breakout raise serious and important issues. But as Senator Pressler said on January 30, 1984 in his remarks to the "Workshop on Arms Control in Space" organized by the Congressional Office of Technology Assessment, "The ASAT problem is . . . only the forward edge of a potentially ominous trend in the military uses of space." This makes it all the more urgent to pursue serious negotiations in a timely fashion.

The Administration position emphasizes the potential vulnerability of the high-value U.S. satellite platforms to ASAT activities that the Soviets might undertake in violation of treaty provisions. From a technical point of view, that is hardly the place for the United States to give primary emphasis to its concerns. There are appropriate actions that the United States should initiate to enhance security of our satellites against the threat of hostile action, and to improve the ability to monitor compliance with ASAT restraints. However, it is generally much more difficult and expensive to go after satellite platforms in space rather than to destroy, damage, or otherwise interfere with the few large and relatively vulnerable ground stations. The electromagnetic links of the satellites to ground are also much more vulnerable to disruption—except in the case of the most advanced technology.

Given the operational difficulties and the high energy requirements, it will be years before a practical and reliable ASAT that depends on intercept and destruction of space platforms will exist, capable of competing with the alternative means available to the Soviet Union for destroying the effectiveness of these systems as mentioned above. In making this statement I include the currently existing and very modest Soviet orbital intercept capability. Now is the time—before it is too late—to start and pursue with urgency the negotiating effort to head off such threats that would be counter to U.S. interests. It is also the time to redress potential near-term threats by improving the survivability of our satellite ground stations and by making our communication links to space more jam-proof.

I believe it is strongly in the national security interest of the United States to enter into prompt and vigorous negotiations for balanced and verifiable ASAT limits. U.S. satellites for early warning, intelligence, and military communications are of great importance to our security and to reducing the risk of war—especially in view of the nature of the United States as a sea power with extensive, vital overseas interests and commitments, and in view of the tightly closed character of the society of our principal military adversary, the Soviet Union. We should therefore seek ASAT Treaty restraints that improve their survivability. A very useful and practical first step, en route to more comprehensive restraints that may be more difficult to achieve, would be to negotiate a ban on testing. I support Senate Joint Resolution 129 declaring "an immediate mutual and verifiable moratorium of limit-

[4] Initially against satellites in low-earth orbits at altitudes below 1,000 kilometers, and eventually up to synchronous orbit altitudes of 40,000 kilometers.

[5] In its Report to the Congress on U.S. Policy on ASAT Arms Control (Mar. 31, 1984).

ed duration on the testing in space of antisatellite weapons," and calling for immediate resumption of negotiations toward a comprehensive verifiable treaty limiting ASAT.

CONCLUSION

I see no prospect today of finding a technological fix to our perilous strategic situation with nuclear weapons. The path to a more secure world must be paved, at its start and for a long distance en route, with constructive efforts at understanding and negotiating toward reducing their threat. This makes it all the more important for us to pursue effective arms control with the Soviet Union, while simultaneously maintaining stable and secure deterrent forces. The absence of Soviet space-based and space-directed weapons—both ABM and ASAT—does a lot more for our deterrence and strategic stability than would the existence of such U.S. weapons.

While working toward a long-term goal of making nuclear weapons obsolete, a goal of considerable merit, we must also use a mixture of diplomatic and defense measures to work to ensure that the nuclear weapons are never used. For the present, I believe this calls for reaffirming the basic concepts of the United States-Soviet strategic relationship as reflected in the ABM Treaty. It also calls for us to make a determined effort—through sensible program restraints as well as through negotiations—to keep space from being one more dimension of unnecessary weapons competition between the United States and the Soviet Union.

Senator PRESSLER. Thank you.

Dr. Carnesale.

STATEMENT OF ALBERT CARNESALE, PROFESSOR OF PUBLIC POLICY AND ACADEMIC DEAN, JOHN F. KENNEDY SCHOOL OF GOVERNMENT, HARVARD UNIVERSITY, CAMBRIDGE, MASS. (Resumed)

Mr. CARNESALE. Thank you, Mr. Chairman. I appreciate this opportunity to express my views on the implications of ASAT weapons and the Strategic Defense Initiative. I would like to focus on the relationship between the two.

Strategic defense is not a new idea. Invulnerability has always been preferred to vulnerability, and all the more so in the nuclear age. So President Reagan's speech of March 23, 1983, understandably appeals to all of us. The problem is that we have no idea of how to achieve the goal of invulnerability, or anything close to it. And that has been the situation for a long time.

So what is new in the area of strategic weapons? I will focus particularly on the question of defense against ballistic missiles.

One of the things that is new is the acronym. We have gone from ABM to BMD to DABM to SDI. But it is not only the acronym that has changed. There have been some changes, as Professor Drell pointed out, in the technology of conventional systems using radars and interceptors and launchers for them. Those things can not be built much smaller, more capable, and with much better data processing capability.

Exotic systems, the systems using things like lasers or particle beams or other forms of directed energy, were long gleams in the defense scientists' eyes. They still are largely gleams in those eyes, although the gleams are coming a bit more sharply into focus.

There is some exciting science, but as I indicated earlier, some frightening engineering from the point of view of actually trying to make a workable weapons system. What we have found are some sexier new ways to shoot down a single reentry vehicle or a single missile. We have known how to do that for decades. The problem was not whether you could shoot down a bullet with a bullet. We

knew how to do that. The question was whether you could shoot down thousands of bullets simultaneously. Some of the bullets look like bullets, some do not, some you might not be able to see at all, and some might be maneuvering bullets. That remains the tough part of the defense problem.

The problem was and is with numbers and with countermeasures. It is not a question of whether we have a new, cute way to destroy a reentry vehicle or a missile in flight.

There have also been advances in the threat facing ballistic missile defenses. I get concerned when people get excited about a potential defense that would have worked against the Soviet missile force of 1970. The question is whether the United States will develop a defense that could deal with the Soviet threat that we will face when the defense is ready.

What is this ballistic missile defense supposed to do? This too has changed with time, although the changes seem to be taking place more rapidly recently. When the idea was first thought of, people had in mind a thick nationwide defense of the population. That wasn't achievable, so people talked about a thin defense of the Nation.

Then even that did not look so promising, so we switched to a defense against Chinese ICBM's, which was a little easier because they did not have any. That was a distinct advantage.

Then came the MX. We started to think about a defense only of those ballistic missiles in their Densepack configuration. With the President's speech, we returned to something which certainly sounded like a thick, nationwide defense. Now we seem to be talking about a thin defense that just makes the other side's attack more complicated.

So as to the question of what is the mission of a ballistic missile defense system, the answer seems to depend not only upon who is answering, but when.

Again I would mention the threat. When the United States had its ABM debate last time, the threat was less than 2,000 Soviet reentry vehicles. It is now 7,500 or so, and we are talking about a defense that would not be in place until beyond the year 2000.

When we talk about defenses, we should not be talking about last year's threat or even today's threat; it should be the future threat.

On the political side, we have moved from a cold war, to a period of détente, to a period of disappointment, and back to a cold war. We moved from Vietnam, through the post-Vietnam phase, to what might be the post-Grenada phase. These changes affect our thinking about strategic defense. And the Strategic Defense Initiative is the President's initiative, and that makes it different than any other kind of initiative.

By far the most important change since the last debate over ABM is the existence of the ABM Treaty. While I will not go through all the provisions of the ABM Treaty—that is not necessary—it is worth reminding ourselves of a few that are particularly relevant to the Strategic Defense Initiative.

First, the ABM Treaty makes clear that there is to be no nationwide defense. That is simply prohibited. This principle appears in the first article of the treaty.

Second, the treaty defines an ABM system in terms of capabilities. An ABM system is a system for countering strategic ballistic missiles or their elements in flight trajectory. An ABM system is anything that can do that, regardless of what you call it, whether star wars or gizelstops or wizzledus. If it can counter strategic ballistic missiles, or their elements in flight trajectory, it is an ABM system and it is covered by the treaty.

Third, the treaty prohibits development, testing, or deployment of any strategic ballistic missile defense systems or components other than fixed land-based ones. It says that explicitly, there are to be no space-based systems or components.

Finally, with regard to systems based on lasers or particle beams or other exotic technologies, there is to be no deployment of them at all, not even on the ground, not at all. To permit deployment of such systems would require amendment of the treaty.

I will now discuss briefly some relationships between ballistic missile defense and ASAT. Professor Drell covered much of what I would have mentioned.

The capabilities required for boost phase ballistic missile defense overlap greatly with those required for antisatellite warfare. And again, we should not focus solely on cute technologies. As one of my colleagues at MIT, Jack Ruina, is prone to remind us, we have long known how to destroy a ballistic missile in early boost phase. You could do it with rocks, or with a machinegun. The problem is countermeasures. The Soviets are not likely to allow us to have a machinegun standing in front of each of their launch silos. But if we could do that, we could destroy those missiles.

So the problem is not how do you destroy one, the problem is how do you destroy one against a noncooperative adversary? Almost all of the concepts being discussed require either space basing or something like a popup system. They also require directed energy, or something else that moves at the speed of light.

Such systems are clearly prohibited by the ABM Treaty. You cannot even devlop such a system yet alone test it or deploy it. And, as was mentioned earlier, such a system would likely be vulnerable to ASAT.

Midcourse ballistic missile defense also has a great deal of overlap with ASAT. Indeed, the miniature vehicle that sits astride the F-15 aircraft as part of our advanced ASAT system was developed as part of a midcourse ballistic missile defense system.

Terminal ballistic missile defense overlaps least with ASAT. It is interesting to note, however, that the current controversy with the Soviet Union over the radar in central Siberia may stem from this overlap. The United States maintains that the radar looks an awful lot like an ABM radar or an early warning radar. The Soviets maintain it is a space track radar. A space track radar could have very useful antisatellite capabilities. Even at the terminal defense level, ABM and ASAT capabilities overlap.

The ABM Treaty inhibits, but certainly does not preclude, antisatellite capabilities. The ASAT task is the simpler one. So even if you do away with ABM completely, you may not be able to constrain ASAT completely. Arms control agreements governing ASAT would serve to reinforce the ABM Treaty.

Without any ABM Treaty or similar constraints on ABM systems, ASAT would be unlimited completely. That bodes ill for any strategic defense system to be deployed in space.

In response to Senator Tsongas' earlier question about the connections between star wars and stability, I used this example: Suppose we and the Soviets both had star wars systems deployed in space. The incentive to strike first against the other fellow's star wars satellites would be great because you could simultaneously accomplish two goals. One, you render his homeland vulnerable to your offensive forces, and two, you keep your homeland invulnerable to his offensive forces. You can hardly beat that. If you do not go first, and he does, the situation would be reversed. The effect on stability would be likely to be catastrophic.

Finally, I offer some thoughts on what to do. First among the things to do is to avoid the fallacy of the last move. Do not even think in terms of the United States alone having a strategic defense. Such a situation clearly would be desirable. We would all like it. It is not a realistic alternative, despite the fact that it may be preferable. Either both sides are going to have strategic defenses or neither side is going to have them. If both sides have them, we have all the problems of penetrating a Soviet defense that does not now exist and is prohibitted by the ABM Treaty.

There is another aspect of the fallacy of the last move. We must recognize that any defense would face a reactive threat. A defense system to be deployed 30 years from now that could deal effectively with the SS-18 of 1984 is not very comforting.

Second under what to do relates to Soviet ballistic missile defense. If we are worried about Soviet ballistic missiles defense, then we should be strengthening the ABM Treaty with limitations on ASAT, on antitactical ballistic missiles, and on large phased array radars. We should be developing far more actively penetration aids for our offensive missiles, and perhaps deploying some, and we should be working harder on shortening the leadtime for deployment of conventional ballistic missile defense to maintain Soviet interest in the ABM Treaty.

Third, if we are concerned about Soviet antisatellite capability, we should be taking appropriate countermeasures, such as hardening our satellites, making them able to maneuver, providing spares, or as I indicated, negotiating arms control agreements to reduce that threat. Star wars does not reduce the vulnerability of American satellites.

Fourth, we should examine BMD systems, with the emphasis on "systems," and try to identify any fatal flaws they might have. I would pursue a strategic defense initiative that is a research program consistent with the ABM Treaty. Its objectives would be to hedge against Soviet accomplishments in this area, and second, to move toward the possible but unlikely goal of eventually achieving a world that is dominated by defenses rather than offense.

Fifth, I would continue our antisatellite programs unless and until an ASAT arms control agreement were reached. But I would beware not to undercut the ABM Treaty.

In closing, I note again that invulnerability is attractive, but not available. Deterrence as we know it now is a fragile shield, but it is the only one we have. A safer world would be more desirable, but

we do not know what it looks like or where it is, let alone how to get there. We ought to try and find out if it does exist, and where it might be. Then and only then, should we embark on the path to get there. But the thing to avoid at all costs is creating pressures and monentum, as we are doing now, that may force us prematurely to go somewhere just because we feel we have to go somewhere. The somewhere might be far, far more dangerous than where we are now.

Thank you, Mr. Chairman.

[Mr. Carnesale's prepared statement follows:]

PREPARED STATEMENT OF ALBERT CARNESALE

I appreciate this opportunity to express my views on antisatellite (ASAT) weapons and strategic defense. My testimony focuses on the relationships between the two and the implications of those relationships.

Strategic defense is not a new idea. Americans, like others, have always preferred an invulnerable homeland to a vulnerable one. While the goal is a simple one, its achievement eludes us. Against large modern forces of strategic nuclear delivery vehicles, especially long-range ballistic missiles, invulnerability is not an available option; not now, and not for the foreseeable future. Nor are we likely to achieve soon anything that even remotely approaches invulnerability.

This all sounds familiar: it has been the situation for decades. That is not to say that nothing has changed. One thing that is new about strategic defense is the acronym. We've seen the transition from ABM (Anti-Ballistic Missile), to BMD (Ballistic Missile Defense), to the rather short-lived DABM (Defense Against Ballistic Missiles) and, most recently, to SDI (the Strategic Defense Initiative). The SDI is intended to include defense against all forms of strategic delivery systems, not just against ballistic missiles, but the BMD task remains dominant and is the subject of my attention here.

There have been important developments in the world of BMD. The technology has clearly moved forward. "Conventional" BMD systems, based on land-based radars and interceptor missiles, can be made far smaller and more capable than they used to be. "Exotic" BMD systems, using components based on physical principles different than those used in the conventional systems, are still gleams in the eyes of defense scientists, but the gleams are coming more sharply into focus. There have been some exciting scientific advances, but the problem of producing an effective defensive system looks as tough as ever. The difficulty lies not in "hitting a bullet with a bullet"; it lies in coping simultaneously with thousands of "bullets" and with potential countermeasures implemented by a non-cooperative adversary. As defensive technologies evolve, so too do the offensive systems with which they must deal, and the offense already enjoys an enormous head start.

The military mission to be accomplished by BMD also keeps changing. Most of us can recall the shifts from a nationwide defense against all possible attacks, to a thin nationwide defense against (then nonexistent) Chinese ICBMs, to several localized defenses of our land-based strategic missiles and bombers, to a concentrated defense of a dense-pack deployment of MX missiles and, to complete the circle, last year's return to a thick nationwide defense against all possible attacks. More recently we hear that the SDI is not expected to "intercept and destroy strategic ballistic missiles before they reached our own soil or that of our allies." The goal of SDI apparently is now more modest than that envisaged in the President's speech of March 23, 1983. What is the military mission to be accomplished by BMD? The answer depends on who is answering, and when.

The political context for strategic defense is not static either. Detente has been replaced by disappointment. America has emerged from its post-Vietnam era and may be entering its post-Grenada phase. And the Strategic Defense Intitiative is the President's initiative, not something with which he is merely going along.

Perhaps most important of the changes that have occurred in the world of BMD was the entry into force in 1972 of the ABM Treaty. It is useful to recall some of the basic provisions of that agreement:

Nationwide defense is prohibited. Article I states that, "Each Party undertakes not to deploy ABM systems for a defense of the territory of its country. . . ."

ABM systems are defined in terms of capability. Article II provides the basic definition: ". . . an ABM system is a system to counter strategic ballistic missiles or their elements in flight trajectory." Any system which can defend against strategic

ballistic missiles is, for purposes of the treaty, an ABM system. For example, if an air defense system were to have ABM capabilities, it would count as an ABM system.

Only fixed land-based ABM is allowed. Article V states that, "Each Party undertakes not to develop, test, or deploy ABM systems or components which are sea-based, air-based, space-based, or mobile land-based." Only fixed land-based systems are allowed to move beyond the laboratory research stage, and only the so-called "conventional" ABM systems can move as far as deployment.

"Exotic" ABM systems may not be deployed. The Treaty, unlike anything in the American legal tradition, employs as a principle the notion that what is not permitted is prohibited. Article III begins with, "Each Party undertakes not to deploy ABM systems or their components except that . . . ," and then it specifies the permitted deployments of fixed land-based radars, launchers, and interceptor missiles. No other ABM deployments may be made, and this prohibition applies to exotic as well as to conventional ABM systems. A statement agreed to by the two Parties makes clear that amendment of the Treaty would be required to permit deployment of any "ABM systems based on other physical principles and including components capable of substituting for ABM interceptor missiles, ABM launchers, or ABM radars."

How does all this stuff about BMD relate to ASAT? Consider first the overlap between BMD and ASAT technologies.

Boost-phase BMD systems (i.e., systems which attack ballistic missiles while they are in powered flight) would have great ASAT potential. Indeed, the ASAT challenge is in many ways less difficult than the BMD one. A ballistic missile attack would present a greater number of targets, each less vulnerable than most satellites, and would provide less time for the destruction of each target. Of course, the ABM Treaty already prohibits deployment of boost phase BMD, since such a system almost certainly could not be fixed and land-based, and very probably would make use of "exotic" physical principles.

Mid-course BMD systems also overlap strongly with ASAT systems. This is unavoidable because the midcourse portions of ICBM trajectories are similar to those of some satellites in orbit. For example, the Soviets' Galosh ABM system has some ASAT capability, and the U.S. miniature vehicle ASAT weapon evolved from a design originally intended for midcourse BMD. Because the ABM Treaty severely limits the numbers and locations of ABM interceptor missiles, the potential ASAT capability of these permitted ABM systems does not pose a very significant threat.

Terminal BMD has the least overlap with ASAT technology, but there is some. The overlap lies primarily in the radars employed for early warning and tracking, for these radars could also serve crucial roles in conducting anti-satellite engagements. The ambiguities and disputes associated with the large phased-array radar under construction near Krasnoyarsk near central Siberia serve to illustrate this connection between BMD and ASAT technologies.

It is clear that the ABM Treaty inhibits, but does not preclude, the continued development and deployment of ASAT weapons systems. On the other hand, a treaty limiting ASAT activities almost certainly would strengthen the ABM Treaty. For example, an ASAT Treaty probably would prohibit flight testing of mid-course BMD systems.

Without the ABM Treaty or something like it—that is without meaningful constraints on the development, testing, and deployment of boost-phase, mid-course, and terminal BMD systems—ASAT activities would be unlimited. If one can develop systems to perform even modestly well the extraordinarily difficult BMD task, those same systems are likely to find the ASAT task to be a piece of cake.

Imagine a world in which we and the Soviets, despite the technical, military, and political obstacles, had managed to deploy highly effective space-based BMD systems. Such systems almost certainly would be far more effective in an ASAT role than in a BMD role, simply because the ASAT task is the far easier one. Thus, each side's "Star Wars" BMD satellite's would be vulnerable to attack by those of the other side. Think of the effect that that would have on the incentive to strike first; that is, on the incentive to start a strategic war. By going first in this hypothetical world, one could destroy the adversary's Star Wars satellites through the use of one's own. This action not only renders the other side's homeland vulnerable to attack by offensive missiles, but, at the same time, assures the continued invulnerability of one's own homeland. An unconstrained Star Wars world could pose the gravest imaginable threat to stability in the nuclear age.

Invulnerability remains an admirable and understandable ultimate goal, but the path from here to there, if it exists at all, has yet to be identified. The current state, in which offensive weapons overwhelmingly dominate any defenses, is repugnant,

but it does serve to deter nuclear war. This fragile shield of deterrence must not be weakened until we have something stronger to stand between ourselves and nuclear annihilation. I believe that the interest of the United States would be better served by strengthening the ABM Treaty than by undermining or circumventing it. Among the most serious threats to the Treaty are incipient deployments of weapons systems intended primarily for missions other than defense against strategic ballistic missiles which, nevertheless, have (or would be perceived to have) substantial strategic BMD capability. Such systems include not only ASAT weapons, but also antitactical ballistic missile and advanced air defense systems. Our response should be to engage the Soviets in an attempt to mitigate these threats through effective arms control.

The search for a replacement for the current system of deterrence should be intensified, but let us not pretend to others or to ourselves that we know either where we are going or how to get there. And until we know of a path that leads to a safer world, we had best not launch the expedition.

Senator PRESSLER. Thank you very much.

Since you just finished, Dr. Carnesale, I might ask you, you helped negotiate the ABM Treaty. One of the conclusions of the Office of Technology study, their eighth point, was that—and you have covered this a bit but, you might expand—deployment of missile defenses based on new technologies is forbidden by the Anti-Ballistic Missile Treaty reached at SALT I. That treaty permits only restricted deployment of traditional BMD's using fixed ground-based radars and inteceptor missiles. Research into new technologies and, in selected cases, development and testing of defense systems based on these technologies, are allowed within the treaty.

Are we on the verge of violating the Anti-Ballistic Missile Treaty that you helped negotiate? And you have covered this to some extent, but could you briefly summarize where we stand in regard to that, in this whole proposal?

Mr. CARNESALE. No; in the short term we are not. There is nothing that I know of in the Strategic Defense Initiative, particularly the new programs, that would violate the treaty in the near term.

But, certainly, to achieve the ultimate objective of the initiative would require violation of the treaty eventually.

Let me illustrate the point. There are no limits in the treaty on laboratory research. There are no constraints on research on particle beams or lasers. Indeed, at permitted ABM test sites—of which there are two—you could test fixed, ground-based lasers or particle beams as ABM systems. But to go the next step and put one of these devices in space would be a violation of the treaty. One cannot develop space-based systems or components. And the word "develop" in the context of the treaty means to build a prototype.

Senator PRESSLER. OK.

Mr. CARNESALE. To proceed all the way down this path would require modification or abrogation of the treaty. But there is no problem in the near term. Indeed, there were programs planned before the Strategic Defense Initiative that probably would have run up against the treaty sooner than the new programs. For example, one of the midcourse intercept schemes used multiple, independently guided interceptor missiles that would home in on different reentry vehicles. Such systems are prohibited by the treaty.

Senator PRESSLER. Would each of you respond to this assertion?

How do you respond to the argument that if strategic defense is going to make us a little safer, why not build it? If it makes us 2

percent safer, why not build it? If it makes us 10 percent safer, why not build it? That is what people say to me when I say we should negotiate first and certainly try to get this thing stopped, although I do support research during the interim.

What would the answer to that be?

Mr. CARNESALE. The ability to intercept 2 or 5 percent of Soviet RV's does not make us 2 or 5 percent safer. Indeed, if such a defense made it more likely that they would launch an attack, it would have made us less safe than we were before.

If I thought it really would make us 2 or 5 percent safer, then depending upon what it costs, I would probably be in favor of it.

Senator PRESSLER. So you would say it does not make us any safer.

Mr. CARNESALE. To be fair, without knowing what the system is, I do not know whether it makes it safer or not. Nobody is proposing that we build a defense today. That is not what the debate is about. It is about whether to start down a path and to build up momentum to conduct tests and possibly to deploy systems that may violate a treaty, when we have no idea why or where we are going.

Senator PRESSLER. Are there other comments?

Dr. DRELL. If I thought that we would have a safer world by a path like this, I would indeed support it. The problem is that as a unilateral initiative, as I said in my prepared remarks, based upon a decision taken unilaterally by the United States, we have to ask how will the Soviets react or how would we react if the Soviets did the same thing, and will this contribute to making the world safer.

Permit me to read a short quotation from a former President of the United States who faced this decision in 1969 when he decided not to build a nationwide defense, and when he announced it to the Nation. It was a statement by President Nixon: "Although every instinct motivates me to provide the American people with complete protection against a major nuclear attack, it is not now within our power to do so." I think you heard this morning that is still a true statement. It is not now within our power to do so. "The heaviest defense system we considered," the quote goes on, "one designed to protect our major cities, still could not prevent a catastrophic level of U.S. fatalities from a deliberate, all-out Soviet attack."

Again, that is a statement that we have heard since President Eisenhower. It is the nature of nuclear weapons and their enormous destructive power that if even one lands on a city, that is the end of the city. But then, the key sentence of President Nixon's speech on March 14, 1969—"and it might look to an opponent like the prelude to an offensive strategy threatening the Soviet deterrent."

I think that is the problem. Without arms control retraints, a unilateral change in the fundamental strategic relation, going for defenses at the same time as we are strengthening our offense, faces them with a view we would like no more if we saw it coming at us: namely, a major enhancement of offensive forces to preserve the retaliatory or deterrent capability, and at the same time, a defense which, as an adjunct of a first strike, would have to handle only a surviving retaliatory force—drizzle instead of a downpour

coming back—and could be more effective. And that is the problem. It is destabilizing.

Senator PRESSLER. I am going to yield to Senator Pell. I have several other written questions, but this morning Richard Perle and I had a little debate, and we had the same debate on TV recently. I wrote an op ed piece in the Los Angles Times on the theory that MIRV's were analogous to this current debate we are having on star wars. We did not have any moratorium on the research and development and testing of MIRV's. As a result the other side then reacted and deployed MIRV's, giving us reduced security. Is there an analogy? We were told that that was going to deploy MIRV's—that was long before I came to Congress. We were told that that was going to be the strategic ace card, that once we had MIRV's, we were safe and nobody would challenge us. Well, the other side reacted. But is that a valid analogy? Is star wars of the 1980's the MIRV's of the 1960's?

Dr. DRELL. I believe it is, Senator. The MIRV's were originally designed to maintain, to enhance the effectiveness of our deterrent force in the face of the initial, limited Soviet ABM deployment around Moscow, and in anticipation of further systems growth based upon suspicious doings around Tallinn and Leningrad. And one could indeed defend it at that point, as we saw an ABM being developed unilaterally by the Soviets, saying we must preserve our deterrent, something President Reagan has said in connection with this initiative, too, in his speech of March 23.

However, we then saw a SALT I Treaty negotiated, to which these gentlemen on my left contributed, which removed the rationale for the MIRV. Yet the momentum in the program carried it forward even without that argument, and now we have an excess of Soviet MIRV's, and they themselves have become a focus of a greater strategic instability than we suffered before the MIRV's. And we have MX programs, we have ICBM basing programs. We have more warheads, and we have greater danger.

I believe the analogy is correct.

Mr. CARNESALE. I believe there is merit to the analogy, but like all analogies, one has to be careful not to push it too far. A world in which there were no defenses and lots of MIRV's, which is essentially the world we are in now, is a rather stable one. But it is rather disquieting because, if a war starts, it is going to be Armageddon. A world in which there were lots of defensive systems and relatively few offensive systems would be somewhat more attractive.

If you push the analogy to extremes, it falls apart, but I think at first cut it does have merit.

Senator Pell asked this morning about the MIRV negotiations. I may be able to add to that discussion.

Both the United States and the Soviet Union made MIRV proposals in SALT I, the United States first. It was part of a larger package, but the short form of what we offered was a prohibition on testing and deployment. At that time we had already tested MIRV's, we had them stockpiled, and we were starting to deploy.

The onsite inspection that we called for was not only onsite inspection of Soviet offensive missiles, but also onsite inspection of Soviet air defenses, to be confident that those would not be upgrad-

ed to ballistic missile defenses. The Soviets had then and have now about 10,000 surface-to-air missile launchers spread all over the Soviet Union, so this amounted to a proposal for onsite inspection everywhere in the Soviet Union.

The Soviets asked if they understood our proposal correctly. It seemed to them that it would prevent them from testing MIRV, which they had not yet done, whereas it would permit us to continue to produce and stockpile the MIRV systems we had already tested. They had understood our proposal correctly. [General laughter.]

The Soviets came back with a counterproposal. They said, we have a MIRV proposal of our own. No production and no deployment, and no onsite inspection. We said, wait a minute, let us make sure we understand this right. Your proposal have production and deployment, which only we are capable of doing, because you have not yet tested MIRV. At the same time, your proposal permits testing, so you can catch up to us. They said we understood their proposal correctly. [General laughter.]

Now, it was obvious that there was a counterproposal that either side could have come in with if they were really interested in a MIRV ban: no testing, no production, and no deployment, with verification provisions to be negotiated.

Neither side made that proposal. Why were we not interested? Because we were ahead. Why were they not interested? Because they were behind.

This is typical of the field of arms control. You either get things before they start or they get out of hand.

The ABM Treaty stopped defensive systems before they got away. It is a unique agreement that banned things that did not yet exist, that people had not even thought of. The word "laser" does not appear there and the words "particle beam" do not appear there, but these systems are covered.

Unlike the American legal tradition, the ABM Treaty specifies what is permitted, and everything else is prohibited. We caught this genie; let's not let it get away.

Senator PRESSLER. I think that is a good point. I have oftentimes said I think mankind is on the verge of a great, new, expensive arms race in outer space. If we do not stop it this year or next year, it will be impossible to halt, the floodgates will be opened, and we will go on to the next level, so to speak, which will be in my view a very expensive one. The DOD has estimated it will cost $100 billion to $500 billion to build these systems.

Do any of you have any estimates that you have worked up? And this is my last question, and I am yielding to Senator Pell after this. Just briefly, are those realistic estimations for building such a system, apart from operating it?

Mr. CARNESALE. I cannot estimate the costs of systems when I have no idea of the specific technologies on which they are based. In this case, I do not even know the science on which they are based. So I do not have any cost estimates.

Dr. DRELL. I do not think there is an honest cost estimate. I recall that the week after the President's "Star Wars" speech, Charles Mohr had a column in the New York Times, March 31, 1983, in which he quoted from unclassified Pentagon testimony a

space-based laser as one layer of a defense costing in 1981 dollars $500 billion, one layer of these many layers.

Senator PRESSLER. We are talking about several layers.

Senator Pell.

Senator PELL. Thank you very much, Mr. Chairman.

Ambassador Buchheim, when you were conducting negotiations concerning ASAT, did you believe the Soviets seriously wanted an agreement? What was your feeling?

Ambassador BUCHHEIM. Yes, sir, I did believe that, and I still believe it. I believe it is true today. A lot of people say that the Soviets continuously and invariably lie, cheat, and steal. They might have tendencies in that direction. However, when they say over and over again they would like to resume those negotiations toward that end, at some point I think we ought to consider the possibility that they are telling the truth.

Senator PELL. What was the main obstacle? Was it Afghanistan? What broke up the talks when you were running them, Afghanistan?

Ambassador BUCHHEIM. The talks never did break up. If one rakes around the Old Executive Office Building, I think the record he would find is they are still in existence. In fact, I am still the head of the delegation, and a fine man from the Joint Chiefs of Staff is still, according to the formal records, the Deputy Head.

Now, all of that has no modern relevance, but the point that does have relevance is they never were broken off. They simply did not resume.

We met for three rounds. The third round was in Vienna in the summer of 1979, and as is typical in most of these cases, additional elements of agreement were found, additional elements were uncovered that both sides felt the need to inquire into a little more closely in their respective capitals. So we had the usual agreement; we will pause now; we have this mutual agenda of things that we need to deal with when we next meet, and when we are ready, we will let you know.

Then, of course, the Carter administration fell into a significant decline; I think that would not be an understatement. The frustrations over ratification of SALT II had an effect. Personally, I have never thought there was any substantive relationship between the two subjects, but nevertheless, they had an effect. The unpleasantness over Poland had a clear effect. Afghanistan had a clear effect. Then what I mentioned earlier in my testimony—I think, frankly, petulance took over and we decided we were going to punish the bear. We were just going to do all sorts of hateful things to him like shut down the beginning of a consulate in Kiev which the State Department had worked hard on for 20 years, which the Soviets never wanted, and clearly to our benefit, but we punished them by stopping that and recalling our people.

Then we went through the grain embargo business which mercifully is over with, which also involved harming ourselves rather than them. We allowed the progressive lapsing of agreements on scientific exchange, cultural matters, medicine, and so on, which, among other things, involved the withdrawal of our medical personnel from—where was the place where the possible biological weapon accident?—Sverdlovsk. We did not even have anybody on

the scene who could answer a simple letter asking was there an outbreak of this disease—anthrax—in Sverdlovsk or not.

Senator PELL. Well, just focusing on ASAT for the moment, what you are saying is that the negotiation could be resumed tomorrow because you have the negotiators available. You presumably would be fired because you had the misfortune to work for another administration, but the machinery could go ahead, is that correct?

Ambassador BUCHHEIM. When I was in The Netherlands in March, the deputy head of the Soviet delegation was there, and we had an interesting and useful chat——

Senator PELL. I can hardly hear you. Perhaps you could pull back from the microphone a bit.

Where did this meeting take place?

Ambassador BUCHHEIM. In The Hague, in The Netherlands. It was mostly on a different subject, but he just happened to be there for his government, and I was there. So we were reviewing old times, and he made the interesting comment that in his office are still the files from those negotiations, including a comparative paper that they prepared for their own use, laying out their position as had been brought through the three rounds, and our positions, and he had them laid side by side, and he remarked on how few differences there were.

Senator PELL. Do you have available now, I wonder, such an item by item, column by column comparison that would be in a nonclassified form?

Ambassador BUCHHEIM. No, sir.

Senator PELL. To put in the record here?

Ambassador BUCHHEIM. No, sir. It is all classified.

Senator PELL. There is no way you could make an unclassified commentary showing the differences between the two sides? I think it would be of great interest to this record, if you can get it.

Ambassador BUCHHEIM. I do not think so, but I can, speaking partly in parables and dark sayings, give you some general ideas.

The first question was that of scope, and when the talks started, the Soviets, for obvious reasons, said, well, let's enter into a bilateral deal that we will not blow up your satellites and you won't blow up ours. Fine. However, unlike them, we are involved in a great number of joint programs with other governments, commercial enterprises and so on.

Now, how to square that circle was not entirely completed, but it does have to be squared.

Now, I mentioned this morning out of any context, or this afternoon, rather, that the international legal situation that surrounds these matters really has taken a big step forward in the accession of the People's Republic of China to the Outer Space Treaty because the Outer Space Treaty rests essentially on the commitment that all concerned will conduct their activities in space in ways consistent with international law.

Now, the fact is, up until December 1983, there was one space power that was not party to that fundamental piece of international law. They are now; and I think an undescribed but significant impediment is now gone.

I think enough is understood these days about the ins and outs of the ASAT matter. This was expressed well in the administration's

report of March 31; one cannot all by himself deal with the ASAT question without recognizing that there do have to be some kind of agreed limits on what you can do in space, and of course, the Strategic Defense Initiative raises at least that in exemplary form.

There is already in the Outer Space Treaty a commitment not to station nuclear weapons in orbit. So there is the beginning of limitations on space activities. Those may have to be strengthened in order to make a practical ASAT agreement feasible because neither party will abandon its right of self-defense. So you cannot just do anything you want up there.

We may have to change the provisions that are now of record as to the status of astronauts, because if you read the Outer Space Treaty, and the Convention on dealing with astronauts, what it says to me, at least, is that those agreements means that astronauts can do anything they want, and they are totally immune from any action.

Now, that clearly does not make any sense. It might have made sense when the treaty was built, but it does not make any sense now.

These matters, such matters, one by one, can be dealt with. Both sides understand what they involve.

Senator PELL. Thank you very much.

The office that you say still exists, although you are not in it at this point, is there anybody else in this office or designated?

Ambassador BUCHHEIM. No, sir, it exists only in the form of paper.

Senator PELL. Right.

Thank you very much.

Last August, as I mentioned this morning, I had quite a long conversation with Chairman Adropov, and in the course of that conversation, he expressed the desire or the willingness to dismantle existing ASAT's and ban new ones.

I was wondering, either Professor Carnesale or Dr. Drell, if you believe the Soviets are not only prepared to admit they have a system but would be prepared to dismantle that system?

Ambassador BUCHHEIM. May I interrupt just for a moment?

Senator PELL. Please.

Ambassador BUCHHEIM. There has never been any question about their admitting they have a system. We talk to them every day about the system.

Senator PELL. Excuse me. I didn't ask that question. I said that they not only are prepared to admit the existence, but are they prepared to dismantle it? That's my question.

Ambassador BUCHHEIM. I think so.

Senator PELL. You do?

Do you both?

Mr. CARNESALE. I think for a sufficient price, they would dismantle anything.

Dr. DRELL. I see no reason not to sit down and put it to them because it is in our interest for them to.

Senator PELL. Now, in the various priorities that we are dealing on in the world today, where would you put the conclusion, the negotiation and conclusion of an ASAT treaty, at the top of the list,

or second or third after some of the other arms talks, such as START? Where would each of you put it on the agenda?

Ambassador Buchheim, what would you do?

Ambassador BUCHHEIM. I would put it rather high on the agenda, sir.

Senator PELL. Why?

Ambassador BUCHHEIM. Because the U.S. space assets that can be threatened by a Soviet ASAT system are extremely important. I would put them ahead even of the ABM Treaty because if we found our essential intelligence collection assets brought under attack, not only arms control would go down the drain, but a whole lot of other things would go down the drain.

Senator PELL. Professor Carnesale?

Mr. CARNESALE. I do not think I would rank it number one, but I would put it in my top three or so, primarily because of the timing. I think the ABM question is more timely. There are some strategic offensive systems coming online now that, if they get deployed in large numbers, will vitiate strategic arms control as we have known it.

Senator PELL. Thank you.

Dr. Drell.

Dr. DRELL. I think I would also put it in the top three, but not number one. First of all, I think it is impractical to think of an ASAT treaty as long as we are going all out toward a Strategic Defense Initiative. This is just a way station, a stopping station on the way there, and until we have clear in our mind that we intend to maintain the ABM Treaty in 1987 when it is reviewed to continue it and not violate it because of being committed to a major new strategic initiative, I think it is impractical to think of ASAT.

Senator PELL. One of the points I came back to several times with Chairman Andropov is the question of verifiability, and he emphasized their willingness to accept verification. I tried to pin him down to onsite verification. He would not be pinned down on that. But he seemed willing to be pinned down on the importance of verification.

What kinds of verifiable controls in ASAT's do you believe are possible, Dr. Drell?

Dr. DRELL. Well, I would make two comments there. First of all, the launch vehicles of the current, primitive Soviet ASAT's are large and distinctive. They have several launch pads. They are well identified vehicles, and therefore test limits I think are relatively straightforward to verify, and even the dismantling of those launch facilities would be very clear and straightforward moves for us to verify.

Obviously what else is stockpiled would be hard to verify. On the other hand, if they have not been tested or are not being tested, they are not an immediate military concern. I do not believe the Soviets have a capable ASAT system now that is of great concern to us. Its failure rate, its geometrical limitations are such that it is really quite primitive. So this is a moment to stop it.

Senator PELL. Dr. Carnesale.

Mr. CARNESALE. Yes. I believe it is at the testing phase. Also, I would be very careful with onsite inspection. It has been grossly

oversold. When you think of scenarios in which it would be used, it generally borders on the useless to counterproductive.

Senator PELL. What kind of verifiable controls do you believe there could be?

Mr. CARNESALE. The difference lies in what is the standard for verification. Mr. Perle asks of arms control verification that it solve all of our intelligence problems. He asks what we are going to do about all these ASAT's that could be covertly hidden in buildings. My response is to ask what he is going to do about them in the absence of an ASAT agreement. Do not expect an ASAT agreement to solve that problem.

A constraint on ASAT testing would markedly reduce confidence in ASAT systems. Such limitations are not perfectly verifiable, but I believe they would enhance the security of the United States.

Senator PELL. In other words, you would lean heavily upon bans on testing?

Mr. CARNESALE. My prime focus would be on testing. I would want some cooperative measures to aid verification. The relevant question is whether the United States would be better off with the agreement or without it, rather than whether or not it would solve all the problems related to ASAT.

Senator PELL. What would be the cooperative measures?

Mr. CARNESALE. One example is to exchange information on which kinds of tests are for what purpose, and when they are to be performed. Both sides will have civilian programs going on, some of which may border on ASAT capability. Knowing what to expect would enhance verification.

Senator PELL. Thank you.

Ambassador Buchheim.

Ambassador BUCHHEIM. Sir.

Senator PELL. What would be your thought as to what kinds of verifiable controls you believe are possible?

Ambassador BUCHHEIM. First off, I think a clarification of what is implied, not stated clearly, in the Outer Space Treaty as what you will not do against satellites. There is clear possibility of reaching agreement on that. If somebody undertakes, for example, not to destroy somebody else's satellite, if they violate that undertaking, we will know it.

Second, I think we can have an adequately verifiable prohibition, not just limitation but prohibition on testing. I think we could ask for the dismantlement in some agreed fashion of the launch facilities and accompanying launch vehicles that are currently being used.

To go beyond that I think is a matter of sitting down with the Soviets and seeing what we can work out. I think a good deal of urgency attaches to doing that because the ASAT scene is going to change. I am quite convinced of that. The airplane launch technique that we have fostered is clearly superior to the techniques of taking off from a fixed site with an all-rocket vehicle.

Now, I believe the Soviets know that. If they did not know it before, we have taught them that, and they are going to do something about it. I fearlessly predict that one of these days we will see a Soviet ASAT program based on the Backfire airplane or something like that.

Senator PELL. Thank you very much.

I guess also a ban on deployment would be reasonably verifiable from national means, satellites.

Would that not be correct? Would any of you disagree with this thought?

Mr. CARNESALE. I would disagree.

Senator PELL. For what reason?

Mr. CARNESALE. Well, simply because there is so much dual capability. For example, the Galosh ABM interceptor has some ASAT capability. What would the ban on deployment mean? The line between ASAT systems and some non-ASAT systems would be somewhat fuzzy, and therefore an ASAT deployment ban would not be strictly verifiable.

That is not to say that it might not be in our interest anyway, but I would not make the claim that it was absolutely verifiable.

Dr. DRELL. One thing to remember is that space as we view it with technology now is two domains, what is called low Earth orbit and the other geosynchronous orbit, and we are moving higher and higher with our more and more important satellites. There is no capability at this point that threatens anything in the high altitude orbits. And that is another reason why test limits now, or dismantling of existing launch sites, would be in our interest because it would maintain a sanctuary for the most important U.S. space assets.

Senator PELL. Right. Thank you.

Thank you very much.

I wonder if each of you might be able to submit for the record, if convenient and you are able to do so, your thought of what would be an ideal draft treaty.

My reasoning for that is this is the kind of thing, if it is brief and clearly written, that when we do get around to negotiations, would be of value to the negotiators as one of the bits of ammunition to throw into the kitty. And if you find this inconvenient or unable to or you do not wish to do it, that would be all right, too. It is just a request.

Senator PRESSLER. I think that is an excellent request, and I think it is a good idea.

[The following information was subsequently supplied by Dr. Drell:]

In answer to Senator Pell's question about a treaty limiting ASAT weapons, I would propose the following as desirable provisions:

(1) Each party agrees not to damage, destroy, or otherwise interfere with space systems of the other parties.

(2) Each party agrees not to test—in space or from ground against space objects—or introduce into orbit around the earth systems or weapons for damaging, destroying, or otherwise interfering with systems—in space or on ground—of other parties.

(3) Compliance will be primarily by national technical means (NTM) and there shall be no interference with these means of verification.

(4) Cooperative measures shall supplement NTM as appropriate—to be worked out in the Standing Consultative Commission. These may take advantage of the fact that ASAT tests generally involve large systems and are difficult to hide. Announcements of space activities and limited presence by observers at space launch facilities could contribute to enhancing confidence of compliance.

(5) Successful initiation of negotiations will be accompanied by a mutual moratorium on ASAT tests.

Senator PELL. Thank you very much, and I must ask the chairman to excuse me at this point. But before going, I wanted to congratulate Dr. Gibbons on his report and say how valid I thought were the eight points that he made in it. I would ask, unless it has already been done, that at least those eight points be included in the record.[1]

Senator PRESSLER. Let me say also that I think Senator Pell's suggestion for us to prepare a draft treaty would be a very good thing.

Senator PELL. If the chairman will forgive me for a moment, I remember doing this with the Environmental Modification Treaty. By doing a draft treaty and sending it up to the executive at the time, it stimulated their thinking. A few years later we saw the treaty signed at the U.N. and ratified.

It is by actually putting down on these pieces of paper these kernels of thought that could help our negotiators when and if they do negotiate.

Mr. CARNESALE. Senator, there already exist several draft treaties, one of which——

Senator PELL. That shows my ignorance.

Mr. CARNESALE [continuing]. Has been under negotiation with the Soviet Union. That is the one that Ambassador Buchheim has worked on.

Senator PELL. That is right.

Mr. CARNESALE. Second, there is a Soviet proposal made more recently at the U.N. Third, the Union of Concerned Scientists has prepared a draft treaty.

Fourth, I doubt the utility of floating more of them. We should not detract too much from the one that has been negotiated with the Soviets and on which there apparently remain not too many differences.

Senator PELL. Is this a classified document or not?

Mr. CARNESALE. I believe it is, but we could work on that.

Senator PELL. That is the problem, you see. I think it is classified.

Ambassador BUCHHEIM. Yes, it is.

Mr. CARNESALE. It is available to the Soviet Government and to parts of the U.S. Government, but not to the U.S. public and Congress.

Senator PELL. That is right.

But what I would appreciate is if you could, maybe cribing a little bit from the classified one, give us one that could be in the public domain.

Ambassador BUCHHEIM. I will not do it, sir.

Senator PELL. No. no, you cannot do it, but the other two gentlemen might give consideration to that. [General laughter.]

Senator PRESSLER. Let me say something before you leave, Senator Pell. As you know, during floor debate of Senate Joint Resolution 129, the opposition has asked for a closed session. Now, granted, a lot of this is closed, but there is this image being portrayed to the public that there is something very mysterious here. Too much of this information is classified, I think, without reason to be classi-

[1] See page 322.

fied. I am certainly not going to ever make public any classified information. But by virtue of having a closed session, the opponents wish to imply that they know something that the public does not know. A great deal of classified material I have seen should not be classified. It would seem that this information is of the type that might fall into that category.

But anyway, be that as it may, I have a few more questions to submit for the record for this panel, and I want to call the last panel forward: Dr John H. Gibbons—and by the way, thank you very much. I thank you very much indeed.

Mr. CARNESALE. Thank you.

Senator PRESSLER. Dr. John H. Gibbons, Director, Office of Technology Assessment; Dr. Ashton B. Carter, OTA consultant, MIT; and Dr. Peter Sharfman, Manager, Office of Technology Assessment.

Also, I would like to insert into the hearing record certain editorials. If we could maintain order in the room, I want to read through the list of editorials I am submitting while the panel is getting into position.

First, from the St. Louis Post-Dispatch "Is Verification Impossible?"; from the Los Angeles Times "Double Standard in Space."

I wish to ask unanimous consent to insert them in the record.

From the Los Angeles Herald, "Satellite Destroyers"; from the New York Times, "Hephaestian Folly in Space"; from the Philadelphia Inquirer, "Stop Satellite Killers at the Negotiating Table"; from the Los Angeles Times, "Infinite Shooting Gallery," from the October issue of Science, an article on ASAT's by Jeff Smith and several other articles and editorials. I have asked to place them in the record.

[The articles referred to follows:]

[From the St. Louis-Dispatch, Mar. 21, 1984]

IS VERIFICATION IMPOSSIBLE?

Speaking before a congressional committee last week Richard Perle, an assistant secretary of defense and one of the hardest of the administration's hardliners, said that he believed that it would be "extremely difficult, if not impossible" to verify any arms control treaty banning anti-satellite weapons.

Mr. Perle's dismissal of the verification issue is but part and parcel of the Reagan administration's drive to block congressional efforts to stop the Pentagon's mad rush to build a new space war capability. The fact of the matter is that, while it may be difficult to verify such a treaty now, it is certainly not impossible to do so. The Soviets' current anti-satellite, or ASAT, system is a crude, operationally limited device using a few old SS-9 ICBMs. Monitoring its dismantltng would be fairly simple. Similarly, a treaty that would ban all ASAT development would greatly simplify verification—any test would be a violation

Mr. Perle's hint that the Soviets may have already deployed some sort of anti-satellite "space mines" is a crude smokescreen. there is no indication that the Soviets have done this and—more importantly—why would Moscow trust such an untested system in a crisis?

However, verification of an ASAT treaty could well become impossible if Washington and Moscow delay on this issue even for a few years. Once the new U.S. ASAT system—a small, operationally flexible aircraft-launched homing missile—is deployed and the Soviets rush to copy it, the ability to verify any treaty banning ASATs will become next to impossible.

The time to ban anti-satellite weapons is now; we cannot afford to wait.

[From the Los Angeles Times, Apr. 9, 1984]

DOUBLE STANDARD IN SPACE

President Reagan set two different standards in as many days last week for deciding whether it makes sense to attempt to write arms-control treaties.

On Wednesday he offered to negotiate a worldwide treaty that would prohibit the "production or possession" of chemicals that can kill or cripple soldiers or civilians. Nerve gases and other deadly chemicals can be produced in garden-variety pesticide plants and probably packed around in canisters the size of basketballs. Making sure that nobody in the world produces or possesses such chemicals is a monumental task—one in which mankind surely has a life-and-death stake but one that the President scarcely mentioned.

Two days earlier he rejected proposals to negotiate a treaty to ban the use of weapons in outer space, saying that verification was virtually impossible, "if not actually impossible." Yet making certain that the Soviet Union does not test a new generation of satellite-killer—and therefore would not be in a position to use one—would be child's play compared with suppressing the production or possession of deadly chemicals.

The President has awesome responsibilities as commander-in-chief, not the least of which is to steer a steady course in matters as important as arms control.

Arms control is not, nor was it ever intended to be, a substitute either for arms that hostile nations need to maintain a relatively peaceful standoff in a dangerous world or for efforts to resolve conflicts short of battle.

The intellectual underpinnings of arms control remain what they were 20 years ago—an extension of security policy designed to reduce the chance of war, reduce the damage of war if the world fails short of the first goal, and reduce the burden of arms on a nation's economy.

In recent years these worthwhile goals have too often been brushed aside by strategic planners who seem to argue that the most important goal of arms control is verification of compliance—no small order, to be sure, in a society as tightly closed as that of the Soviet Union.

Still, giving up the possible benefits of arms control for that reason is like refusing medical treatment unless your doctor signs a written guarantee that you will live forever.

Applying the more rigid standard of compliance to weapons in space means that the United States will proceed with tests of an anti-satellite system far more sophisticated than one that the Soviet Union has tested periodically since the early 1970s, with mixed results. If history is any guide, further U.S. testing will lead the Soviets to start working on a second generation of their own satellite-killer, trying to match or outperform the American version.

The horrors of chemical warfare have been known and feared since World War I, and civilized nations have forsworn the use of chemicals since then. The dangers of weapons in space may seem more remote, but the possibility of a space weapon's accidentally triggering a nuclear confrontation are no less real.

The President's attitude toward verification of compliance with a chemical-warfare treaty is sound. Verification is a matter for negotiation, not a barrier to negotiation. His insistence on a written guarantee in the matter of satellite-killers is not sound. If he were to apply a single standard to arms control, he could direct negotiations on weapons in space to begin tomorrow. If he chooses not to do so, Congress must.

[From the Los Angeles Herald Examiner, Apr. 4, 1984]

SATELLITE DESTROYERS—WE MUSTN'T FALL BEHIND—OR GIVE UP ON NEGOTIATING

At first glance, President Reagan seems to have compelling reasons for his skepticism about the possibility of negotiating a ban on anti-satellite (ASAT) systems with the Soviet Union. In a report to Congress this week, the administration claimed that verifying Soviet compliance would be impossible and asserted that Moscow already has a technological edge.

Ominous as that may sound, it hardly justifies the administration's refusal even to talk with Moscow about a treaty. The Soviets are known to have developed at least one ASAT System—a booster-launched vehicle intended to track and destroy orbiting U.S. satellites. But intentions do not always match performance, and the Soviet system reportedly has failed 11 of its 20 tests. Moreover, even if one assumes the worst—that the Soviets are further along than anyone suspected and may now

have one or two other systems (as Sen. John Warner asserts, based on classified reports)—that would seem to be all the more reason for us to negotiate.

The U.S., of course, has been doing more than refusing to talk where ASATs are concerned. Former Defense Secretary Harold Brown announced back in 1977 that the Soviets had attained a limited anti-satellite capacity. Since then, we've developed and successfully tested (against imaginary points in space, not actual targets) an anti-satellite missile mounted on an F-15 fighter. So far, many experts, impressed with the weapon's mobility and technology, rate it superior to the Russian system.

The fact that the Soviets use the same facilities for ASAT testing as for their nonmilitary space program lends credence to the administration's concerns about the difficulty of verifying compliance with an ASAT treaty. But verification problems are inherent in all arms-control negotiations. The point is that it makes sense, as we proceed with our own development, to make a good-faith effort to keep the arms race out of space, provided that a mutually acceptable method of verification can be found.

The result of refusing to take this two-track, develop-and-negotiate approach would probably be the same as has been the case with other strategic systems, from submarine-launched ballistic missiles to MIRVs. Time after time, we thought we could attain superiority; and, time after time, the Soviets responded to a U.S. advantage by seeking to catch up.

It may be possible to avoid this cycle in the ASAT race. The Soviets have suggested that an attempt be made, and, with no illusions at all about the purity of Kremlin motives, we think the president should take them up on the idea.

[From the New York Times, Apr. 16, 1984]

HEPHAESTIAN FOLLY IN SPACE

When Hephaestus forged a cunning net to catch one of his fellow Greek gods in bed with the wrong goddess, the technology was successful—but the embarrassed victim was so enraged he threw the technologist down from heaven, leaving him with a permanent limp.

The Reagan Administration has its share of overweening technologists who cannot foresee the consequences of their actions—most notably, those bent on building a device to shoot down Soviet satellites. They are renewing a race that will eventually destroy the vital sanctuary now enjoyed by American satellites used for military communications and early warning of attack.

American surveillance satellites compensate for the grave disadvantage of an open society menaced by a militarized closed society. They monitor Soviet activities and compliance with arms control treaties. At present the Soviet Union's erratic antisatellite rocket can't reach the most vital American satellites, all in high orbit. Development of a better rocket would give the Russians an important edge.

Fortunately, they now seem of a mind to quit the race. They have offered a moratorium on further antisatellite tests and have proposed an antisatellite treaty that, while unacceptable in present form, provides a basis for serious discussion.

No doubt they've been brought to the table by a novel antisatellite device being developed by the Air Force. So ingenious is the technology of the new weapon that it can be delivered in an 18-foot missile launched from a plane. The antiquated Soviet device is a 150-foot rocket.

Yet instead of seizing on this opening, the Administration, in a rambling report to Congress, asserts that treaty talks would be unproductive because the problem needs more study. The American ambassador to the Geneva disarmament conference last week accused the Soviet Union of trying to preserve a one-sided military advantage in space.

The Air Force, however, is nearing a point of no return. Once its tests are completed, its antisatellite missile will be so far in advance of its Soviet counterpart that the United States will possess a onesided advantage. Soviet interest in a treaty will probably dry up and the race resume.

An agreement that halted further testing of antisatellite weapons would leave the Russians with a cumbersome weapon that threatens only low-orbit photoreconnaissance satellites. That threat could easily be countered, and the vital high-altitude satellites would keep their sanctuary.

Some may oppose a ban on further tests of antisatellite weapons because it would also curtail certain tests needed to develop a Star Wars defense shield against ballistic missiles. That's a foolish reason to put American satellites in jeopardy. The Air

Force says its weapon would be needed to destroy the Soviet satellites that spy on the American fleet. But even if the satellites cannot be countered otherwise, that hardly outweighs the advantage of keeping American satellites inviolate.

High technology can improve or impair defense, depending on the nature of the race. The Air Force's clever new missile for shooting down satellites, and the Administration's refusal to negotiate, threaten to leave American security with a permanent limp

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[From the Philadelphia Inquirer, Apr. 13, 1984]

STOP SATELLITE KILLERS AT THE NEGOTIATING TABLE

The world stands at a crossroads in its uses of outer space. Decisions the United States and the Soviet Union make now will dictate whether this frontier can be protected or turned into earthlings' next battleground.

One such decision came early this month when President Reagan told Congress he would press ahead with development of weapons, called ASATs, designed to destroy satellites.

Previous U.S.-Soviet talks on ASATs halted in 1979 after the Soviet invasion of Afghanistan. In 1983, the Soviets, despite the breakdown on nuclear arms talks, proposed a treaty dismantling existing ASATs and banning new ones. Congress had required the administration to show "good faith" efforts to negotiate a ban on ASATs, which the Soviets have and the United States is testing. But Mr. Reagan said the United States would not negotiate on an ASAT ban because it would be virtually impossible to verify.

This decision must be reconsidered. For one thing, the impossibility of verification is sharply disputed: Many leading American scientists say a workable ASAT treaty could provide adequate verification safeguards. More important, the very real difficulties of verification should be addressed at the bargaining table, not used as an excuse to avoid it.

Attention has focused on development of satellite-killer weapons because it is at a critical stage. Space satellites have become the nerve center of superpower military operations. But so far neither the Soviets nor the Americans can threaten satellites in high earth orbits where the most important early warning and communications systems are based.

The Soviet anti-satellite weapon at present is slow, ground-based and rather crude; most U.S. satellites are above its range. The United States is developing a swifter, much more sophisticated weapon, launched from an F-15 fighter plane. At its present stage of development the U.S. ASAT would not threaten high orbit satellites but it has the potential to do so. Many experts fear that perfection of the U.S. weapon will spark an unchecked race with the Soviets for better satellite killers.

Why is the administration so determined to press ahead with ASAT development? First, because it believes the United States must have a fully tested ASAT to deter the Soviets from using theirs. Second, because it says a ban cannot be verified.

Some experts contend an unmentioned third reason for the administration's push on ASATs is that a treaty banning them would hinder work on President Reagan's equally controversial "star wars" space defense plan.

The merits of tit-for-tat countering an inferior Soviet ASAT (as opposed to blocking its potential use through other forms of military threat), must be measured against the danger of space weapons race. The United States has the most to lose in such a race. America depends on its more technologically advanced satellites more heavily than does the Soviet Union, both for peaceful scientific and commercial uses, and to provide communications, navigation, intelligence and targeting information for the military.

Moreover, while the United States has a lead in space technology, it could evaporate under a determined Soviet effort, as has happened before.

As for verifying a ban, no one would deny the difficulties. Nor can verification ever be perfect. But claims that reasonably effective verification is impossible are challenged by experts like the Union of Concerned Scientists, which includes former top CIA, military and intelligence figures. They say that any secret attempts by the Soviets to upgrade or add to its present system would require testing that would be detectable. They also believe that use of non-ASAT weapons or space vehicles to threaten satellites would be detectable and that a Soviet "breakout" (breaking the treaty and quickly assembling an illegal ASAT system) would be much harder than the administration asserts.

When calling verification "impossible" the administration often refers to a "comprehensive" ASAT ban. Even the most ardent ASAT foes don't demand a total ban because they know it can't be achieved. But there are ways to address the problem short of that as even Mr. Reagan noted. Congress must continue to press him to negotiate on ASATs before the race for satellite killers moves beyond control.

[From the Los Angeles Times, Apr. 4, 1984]

INFINITE SHOOTING GALLERY

President Reagan says that he will go ahead with plans to turn outer space into a shooting gallery. His casual rejection of pleas to keep violence out of space is foolhardy in and of itself. What it suggests about the Administration's real views on controlling arms of any kind may be worse.

Reagan told Congress this week that he will not even discuss a proposal by the Soviet Union to negotiate ways to keep satellite-killers out of space. That is no surprise; a Pentagon official said as much two weeks ago. But it is a blow to those who see a virtually clean slate on which to write a two-way prohibition on violence in outer space, a far different picture from the nuclear standoff on Earth and the deadly silence at other arms-control bargaining tables.

The President keeps saying that the United States is willing to resume talks on controlling short- and long-range missiles, of which there now are thousands deployed by both major nuclear po ers. His refusal to talk about controlling a handful of weapons that either do not work very well as in the case of the Soviet Union's on-again-off-again anti-satellite program, or have not been fully tested, as with the American satellite-killer, raises serious doubts about the value that the Administration places on arms control of any kind.

The U.S. system, which is about two years from deployment, involves launching small rockets at targets in space from high-flying F-15 fighter planes. The Soviet satellite-killer is more cumbersome, using the space equivalent of floating mines that pull along side targets and blow up, taking the targets with them. Soviet test have not been spectacularly successful.

Reagan's argument for his program depends heavily on a number of straw men. Reagan told Congress that the United States will press ahead with its satellite-killer program in part because there are "significant" difficulties with verifying Soviet compliance with a treaty that would ban weapons capable of destroying satellites—notably those used by both countries for military reconnaissance.

But nobody else is talking about an absolute ban. Even the strongest advocates of arms control in space acknowledge that no treaty could ban research or possession of such weapons. Without on-site inspection, it would indeed be impossible to know who was designing and building what weapons in secluded laboratories. And there are as may good reasons for our not wanting Soviet inspectors tramping around our bases as there are for their not wanting to let American inspectors in.

But a treaty that banned testing could be effective. One trademark of Soviet military research and development is cautious, plodding progress, never deploying anything new until it has been tested over and over. A ban on tests, which could be spotted from U.S. satellites, could keep Soviet weapons out of space, even if Moscow went ahead with research, as this country undoubtedly would.

The President said that Soviet proposals for a ban on satellite-killers are full of "ambiguities and loopholes." But nobody wants him to whip out a pen and sign the Soviet draft. They want him to try to negotiate a treaty without loopholes.

The message says that the United States must continue to "protect against threatening measures." Again, the Administration system is not designed to fend off Soviet statllite-killers but to kill Soviet satellites. America already is trying to make U.S. satellites less vulnerable—the only way to protect them against threatening measures.

Congress appropriated $19 million for further work on the U.S. system last year, but there were two strings attached. One required the Administration to spell out its plans to negotiate an arms-in-space treaty before it could spend the money. Even the rejection puts Reagan in technical compliance with that part of the law. The other string, which passed the Senate on a 91-0 vote, requires the Adminsitration to start negotiations on a treaty before it test-fires any missile at a target in space. Reagan obviously will try to cut that string.

Congress must stick with its position. The fact that the President brushed aside the doubts of Congress about satellite-killers this week sets the stage for a full

debate not only on weapons in space but also on arms control generally. No issue in this election year is potentially more important.

[From Science, Oct. 28, 1983]

ADMINISTRATION RESISTS DEMANDS FOR ASAT BAN

ARGUMENTS FOR A BAN ON ANTISATELLITE WEAPONS GAIN AN INCREASINGLY SYMPATHETIC HEARING IN CONGRESS, BUT REAGAN'S APPOINTEES SHOW LITTLE ENTHUSIASM

(By R. Jeffrey Smith)

Five years ago, for principally selfish reasons, the United States proposed to sign a treaty with the Soviet Union that would have stymied the development of weapons capable of efficiently destroying satellites in outer space. The general idea was that such a treaty was needed—in light of technological developments then on the horizon—to ensure the continued survival of satellites that form the basis of strategic deterrence and arms control verification. A subsidiary motivation was economic: such an agreement would close off costly and unnecessary competition in a challenging area of weapons design.

Despite the considerable appeal of such a treaty, the United States and the Soviet Union were unable to come to a quick agreement, and the talks petered out in the aftermath of the Soviet invasion of Afghanistan. As a result, the development of efficient satellite killers is now nearly at hand, and no agreement on their abolition is within sight. This autumn, the United States will conduct the first space test of a device that can potentially kill critical early warning and military communications satellites orbited by the Soviet Union (Science, 14 October, p. 140). The Soviets, meanwhile, are experimenting with new kill mechanisms on their existing antisatellite weapon, and are threatening to develop an ASAT identical to that now under construction by the United States. Both nations are also working aggressively on more advanced ASAT's, which could in theory use laser beams to destroy orbiting satellites from a great distance. This contest will cost the United States tens of billions of dollars.

A growing number of scientists have become concerned about the size of these expenditures and fearful about where these endeavors will lead. "We believe that the testing or deployment of any weapons in space—in part by threatening vital satellite assets—significantly increases the likelihood of warfare on earth," says a petition circulated last spring by Richard Garwin of IBM and Carl Sagan of Cornell University. "We join in urging the United States, the Soviet Union and other space-faring nations to negotiate . . . a treaty to ban weapons of any kind from space, and to prohibit damage to or destruction of satellites of any nation." The petition has been signed by 36 scientists and retired military officers, including Lee Dubridge, science adviser to President Nixon; Noel Gayler, former director of the National Security Agency; James Van Allen, president of the American Geophysical Union; Thomas Donahue, chairman of the Space Science Board at the National Academy of Sciences; and Margaret Burbidge, chairman of the board of AAAS.

Congress is also becoming interested in stemming the migration of weapons to outer space. Lst July, the Senate Foreign Relations Committee approved a resolution, introduced by Senator Larry Pressler (R-S.D.), urging the Reagan Administration to negotiate a prompt moratorium on ASAT tests, followed by a "mutual and verifiable ban" on ASAT's, and then by a more general prohibition on all space-based or directed weapons systems. "This is a unique opportunity to halt a major arms race before it gets off the ground," says committee chairman Senator Charles Percy (R-Ill.). "Once started, it may prove nearly impossible to stop." A similar resolution introduced in the House by Representative Joe Moakley (D-Mass.) has garnered 124 cosponsors.

So far, these pleas have gone unheeded by the Reagan Administration, which harbors considerable skepticism that a verifiable ASAT ban is possible, much less desirable. Kenneth Adelman, the director of the Arms Control and Disarmament Agency (ACDA), noted last May, for example, that "there are difficult technical problems, including verification problems, that constitute fundamental obstacles to progress in this area. . . . These daunting problems have not been resolved, and we should not rush into negotiations on these subjects until we are ready with verifiable proposals that will enhance national security." He also noted that an ASAT ban would severely limit the Pentagon's ability to destroy Soviet satellites that are used to direct weapons against the U.S. forces. "I am not saying there is an overriding concern but

there is a concern. Thus, there is a dilemma as to whether arms control agreements that would restrict our ability to deal with such satellites are in our national interest."

To date, the Administration has refused to conduct either bilateral or multilateral negotiations on ASAT's, despite the repeated urgings of various European allies—led by Italy—whose own satellites would be endangered by a shooting war in space. Until recently, it was opposed even to the establishment of a formal working group on outer space arms control under the auspices of the United Nations Committee on Disarmament in Geneva. "We want to ensure that, if established, it could usefully undertake full discussion of the relevant issues," Adelman explained last May. This task is of course complicated by the fact that, after studying the matter for several years, the Administration says that it remains unsure what the relevant issues are.

The Soviet Union, in contrast, has recently expressed enthusiasm for space arms control negotiations, and has presented a draft treaty to the United Nations that would require the dismantling of existing ASAT systems and prohibit the development of any future spacebased weapons. In August, at a meeting in Moscow with a delegation from the U.S. Senate, Soviet Premier Yuri Andropov also promised to suspend tests of the Soviet ASAT so long as the United States refrains from "stationing in outer space antisatellite weapons of any type"—an ambiguous phrase that may refer to scheduled testing of the new U.S. ASAT stationed on F-15 jet fighters.

Independent analysts such as John Pike of the Federation of American Scientists say that these initiatives go a long way toward satisfying earlier U.S. complaints. During the formal negotiations in 1978 and 1979, for example, U.S. negotiators were angered by the Soviets' refusal to include satellites orbited by third countries (such as China or the members of NATO), within the scope of a treaty. They also were upset by a Soviet claim that any nation could act against satellite engaging in "hostile or pernicious acts"—a phrase that was generally considered dangerously ambiguous. The United States had also objected to language in a previous draft Soviet treaty that could be interpreted as permitting the use of force against space objects unilaterally regarded as out of compliance with the treaty provisions. None of these objectionable ideas survived in the latest Soviet draft, which states clearly that "it is prohibited to resort to the use or threat of force against space objects in orbit around the earth, on celestial bodies or stationed in outer space in any other manner." Apart from any other considerations, Pike says, "the scope of the new proposals seems to suggest a very real Soviet interest in dealing with the major issues posed by the space weapons competition."

Despite the apparent improvements, the Administration responded negatively to the diplomatic initiative at a State Department press conference on 25 August. Spokesman Alan Romberg noted that, although it was being given careful study, "our preliminary examination . . . suggests that inadequate verification is one of its major weaknesses." In particular, he said it would be "nearly impossible to verify through national technical means alone the dismantling and destruction of the Soviet ASAT system" because it sits atop a rocket booster, the SS-9, that is frequently used for other missions. "We do not know how many . . . ASAT interceptors have been manufactured, and it would be relatively easy for the Soviets to maintain a covert supply of interceptors for use in a crisis. Since satellites which serve U.S. and allied national security are very few in number, any Soviet cheating on an ASAT agreement, even on a small scale, could pose a prohibitive risk."

Pike responds by acknowledging that verification of a ban on possession of ASAT's would indeed be difficult, if not impossible. "Clearly, they are correct," he says. "Even if all the personnel of the CIA, the FBI, and even the Post Office were loosed upon the Soviet Union to roam the country at will, the task of hiding a handful of satellites no larger than a small car would still be child's play." But this is a bogus issue, he suggests, because there is actually no need to seek a ban on ASAT possession. Verifiable restrictions on use, testing, and deployment would be sufficient to undermine confidence that even hidden ASAT's could be effectively used, he says.

Kurt Gottfried, a physicist at Cornell who recently directed a lengthy study of ASAT's for the Union of Concerned Scientists, makes a similar argument. "A treaty that forbids possession presents knotty problems of verification that would require lengthy negotiations," he told a congressional hearing last May. Along with nine other scientists and weapons experts who worked on the UCS report, Gottfried recommends a more modest goal: the United States and the Soviet Union should agree merely to halt all testing of "weapons that can destroy, damage, render inoperable, or change the flight trajectory of space objects."

As explained in the report, such an agreement would immediately freeze ASAT technology at current levels. The Soviets would be permanently limited to their existing system, which works only half the time and is incapable of threatening the communications and early warning satellites necessary for nuclear retaliation by the United States. Any attempts to improve the device or to build something sharply different would be seriously if not fatally handicapped by enormous operational uncertainties. "Tests or use of lasers or high-powered transmitters to damage satellite sensors or to burn out satellite receivers would [also] be banned." Verification will be straight-forward, according to the UCS report, because the United States has in place or under development a worldwide network of sophisticated cameras, radars, and infrared sensors capable of peering deep into outer space; and also because any illegal ASAT tests would create "a host of telltale signs," including an observable launch; transmissions to and from the test vehicle; and possibly some target debris, heating, or displacement.

One aspect in particular of the UCS proposal sticks in the craw of Reagan Administration weapons officials. As even the UCS acknowledges, a prompt ban on ASAT tests leaves the United States without any data on the success of its fancy new device, while the Soviets would be left with useful results from several years of testing its device. As Adelman noted last spring, "it is an asymmetrical relationship and it becomes a serious obstacle at achieving an equitable space arms control agreement. . . . [We cannot] eliminate the decade of Soviet ASAT experience." UCS panelists respond by noting first that the Soviet tests have hardly been a smashing success, and second that a new and even worse asymmetry will be created if tests of the U.S. ASAT are allowed to proceed, due to its vastly superior capabilities (it is smaller, faster, and capable of hitting more important satellites). Garwin predicts that "the Soviets involved in building their own ASAT's will say . . . 'we have to go one more round' " in order to match the U.S. system, and a new arms race will be under way.

Despite the appeal of this argument to some members of the Senate Foreign Relations Committee and the cosponsors of the House resolution, Congress as a whole has listened harder to repeated Administration statements about the disparity in existing U.S. and Soviet ASAT testing experience. During the summer, for example, the House rejected by a wide margin a proposal to delay the initial U.S. test. It also rejected, by a slightly smaller margin, a proposal to delay the purchase of ASAT parts and testing equipment that require a long time to produce. Due to the concerted efforts of a few ASAT opponents, however, both the Senate and the House were persuaded to accept a provision in the annual defense authorization bill that requires a special presidential certification before the U.S. ASAT can be tested against an object in space. Specifically, President Reagan will be required to certify that the United States is endeavoring in good faith to negotiate an ASAT ban and that the initial test is "necessary to avert clear and irrevocable harm to the national security."

Although this is clearly not a high hurdle for Reagan to leap, it has had the effect of forcing his appointees to develop some evidence that negotiations on ASAT's are actually under consideration. Consequently, there has recently been a flurry of activity in quarters where the topic previously excited little interest. ACDA, for example, has begun to talk up a study of ASAT arms control options being prepared by a group of scholars under the direction of William Durch a research fellow at Harvard University. Durch says that ACDA acceded to his request for research funding last July and that a copy of his report is due on 1 February, shortly before the date of the second ASAT test, which involves a space-based target. ASAT arms control options are also under consideration by a formal interagency government working group, which is chaired by a Pentagon official. Measures under discussion reportedly include a treaty that bans only the use of ASAT's, not their testing or deployment, and a treaty that would limit both countries to systems now in advanced stages of development. Administration critics assert that the former would of course be meaningless in the event of U.S.-Soviet hostilities, and the latter would, for reasons already described, give the United States a substantial strategic advantage.

Hardly anyone who desires an ASAT treaty attaches much significance to the working group activity. General Charles Gabriel, the Air Force chief of staff, and Robert Cooper, the director of the Defense Advanced Research Projects Agency, have both publicly expressed opposition to an ASAT ban. A former ACDA official who has been following the issue closely asserts that virtually any significant treaty would conflict with the President's desire to conduct research on space-based antiballistic missile systems, which use similar technology. "It will require, at a minimum, a change in administrations" to achieve an ASAT ban, he says.

The proponents of such a ban believe that the United States is now at a critical juncture in its weapons invention, because successful tests of the U.S. ASAT will soon shatter any realistic opportunity for space arms control. Kurt Gottfried says there is a parallel between today's competition in ASAT's and the development of multiple independently targeted warheads, or MIRV's in the 1970's. MIRV's were developed by the United States in order to counter a primitive Soviet antiballistic missile system, and they provided temporary strategic advantage. But the Soviets soon developed MIRV's of their own, which made U.S. land-based missiles vulnerable to preemptive attack. "Today, at long last, there is general agreement that we would have been far better off had we abstained from introducing MIRV's", Gottfried says. "This lesson applies directly to antisatellite weapons. The Soviets have been both foolish and reckless to spend some 15 years nurturing a clumsy threat against a rather small portion of our satellites. Their major accomplishment has been to provoke us into building a far more sophisticated system. Our ASAT, if deployed, will give us a temporary advantage. But as with ballistic missiles, an ongoing competition in space weaponry will, inexorably, reduce the security of both sides. That should be clear to all by now. Or must we wait . . . a decade hence [to learn] that in 1983 the United States blundered once again by upping the ante in this deadly poker game?"

[From the Washington Post, Apr. 4, 1984]

QUEST FOR NUCLEAR SANCTUARY

It is no surprise to find that, a year after its unveiling, the president's bold proposal for a space-based defense against nuclear attack is under fire. The basic charges are that it would make the Soviets fear the United States intended to attack, that the irreducible weak points in even the most successful imaginable system would leave the country devastated and that the eventual costs would be in the hundreds of billions. What is a surprise is that the informed support for the proposal, in the defense bureaucracy and among defense thinkers, is so qualified. This bears on the current question of the direction and pace of research.

It helps to recall how President Reagan defined his goal a year ago. He urged a quest for a shield so effective as to render offensive weapons obsolete. "I clearly recognize that defensive systems have limitations and raise certain problems and ambiguities," he said. "If paired with offensive systems, they can be viewed as fostering an aggressive policy, and no one wants that." The secretary of defense and the White House science adviser continue to enunciate the initial goal to move from deterrence to defense so as to afford the country nuclear sanctuary.

But the Pentagon's research chief has testified he cannot foresee the day that defensive weapons will not be "paired with offensive systems." Both blue-ribbon panels appointed by the White House to study the idea concluded that since perfect protection cannot be assured, offensive weapons will remain essential.

As a result, in place of a claim that eventually missile defense will be foolproof, the claim is now made that anyway it will strengthen deterrence by imposing new uncertainties on a would-be attacker. The president's goal of ending the current risk to military targets and civilian populations is being eased offstage. Now the research money is being tipped to lesser "intermediate" objectives—guarding against accidental launches, protecting MX holes, reducing casualties, and so forth

It is widely granted that an American move will induce a Soviet move. The Soviets, one of the reports says, are "better prepared than we" to proceed

"We have a nation that can indeed produce miracles," the new head of the program said the other day. Precisely so. If you believe in miracles, you may wish to consider supporting the president's five-year $18-to-$27 billion research program. Otherwise, you will want to take it easy.

[From the New York Times, Apr. 10, 1984]

COURTING A NEW ARMS RACE

(By Peter A. Clausen)

CAMBRIDGE, MASS.—President Reagan began the year with professions of good faith on arms control. But on a key test of this new conciliatory tone—the control of space weapons—he continues to stonewall.

Hiding behind dubious arguments about verification, the Administration refuses to negotiate with the Soviet Union to restrain anti-satellite weapons. In January, the Air Force began testing an anti-satellite weapon, which could squander future hopes of controlling these weapons. Meanwhile, America is pressing ahead with the President's "Star Wars" program—an implusible quest for weapons to shield the American people from nuclear attack by intercepting Soviet missiles in flight. These ill-advised policies foreshadow a new space arms race at great peril to our security.

Anti-satellite weapons are a bad idea whose time, unfortunately, seems to have come. Development of them threatens the satellites we rely on for warning of attack; monitoring arms control agreements; and military command, control and communications. The vulnerability of such satellites to attack would be a highly provocative factor in future United States-Soviet confrontations, and would reduce the chances of bringing hostilities under control if nuclear conflict actually began.

The Administration rejects talks on anti-satellite weapons on the pretext that restrictions on them would be impossible to verify. It is true that an absolute ban on them would pose serious verification problems, but such a ban is not critical. A freeze on testing and deployment could readily be monitored and would achieve the key objective of preventing the further development and perfection of these weapons.

But the opportunity for such a freeze is fleeting. The Administration's verification argument could become a self-fulfilling prophecy if American testing continues. Our anti-satellite weapon is launched from a small missile carried by an F-15 fighter plane. Once operational, this weapon would be very difficult to monitor, since there are no obvious differences between F-15's equipped with the device and those not In contrast, the Soviet anti-satellite weapon is placed in orbit by a huge booster rocket operating from known launch sites. Its previous tests have been closely watched by America, and such a weapon could not be clandestinely deployed.

Neither the American nor the Soviet anti-satellite weapon can now attack the key communications and early warning satellites stationed in high orbits. But this will change if anti-satellite-weapons development continues. A test ban is needed soon to halt development of these weapons while they remain relatively primitive on both sides, and before deployment of our weapons undermines future control possibilities.

Why then does the Administration shun negotiations? For two reasons having little to do with verification. The first is straightforward, if shortsighted: The Administration wants the option of attacking Soviet satellites, even if the price is to forfeit any restrictions on Soviet anti-satellite weapons. The second reason is the "Star Wars" connection. Development and testing of the weapon offers a technological stepping stone to missile defense systems operating in space. This tactic is also legally convenient, since missile defenses are banned by the 1972 Anti-Ballistic Missile Treaty, while anti-satellite weapons remain unrestricted. America plans to exploit this loophole in developing "Star Wars" weapons and is loath to see it closed.

The Administration's approach amounts to playing games with the A.B.M. Treaty, the cornerstone of nuclear arms control. It also undercuts recent American accusations that the Soviet Union is violating the treaty, and precludes any serious attempt to resolve that issue. There is a real danger in all this that the A.B.M. Treaty could come unraveled. This outcome would be all the more tragic because it would be in a lost cause: Independent scientists agree that the hope of defending ourselves against devastation in the event of nuclear attack is an escapist fantasy. It is a dangerous fantasy as well, since the development of missile defenses will inevitably stimulate few offensive arms buildups and make the nuclear balance shakier by multiplying fears and suspicions on both sides.

To prevent a new arms race in space, America must shift course. Two steps are critical: Suspend testing of anti-satellite weapons and start negotiations to halt the further development of them, and give up the costly, futile and dangerous pursuit of "Star Wars" missile defenses. These actions would signal to Moscow that Washington stands by the A.B.M. Treaty and would put us in a position to insist—as we should—that Moscow do the same.

[From the Los Angeles Times, Apr. 9, 1984]

"STAR WARS" HAS BEEN BADLY OVERSOLD

REAGAN'S VISION OF SUPER DEFENSE NEEDLESSLY SHAKES THE BALANCE

(By Ernest Conine)

President Reagan, though sometimes a clumsy diplomat, is a good politician. Otherwise he would not have been twice elected governor of California, then gone on to win the nation's highest office. Nor would he now be in such an excellent position to win reelection as President in November.

That being true, it is hard to understand his bungling of the "star wars" issue.

Both the President and Defense Secretary Caspar W. Weinberger have indulged in sometimes careless exaggerated rhetoric about the purpose and prospects of a stepped-up research-and-development program on ballistic-missile defenses. By doing so they have puzzled and frightened America's allies abroad and handed the Soviet Union a propaganda windfall; they have also given additional fuel to critics at home—all unnecessarily, and all without contributing a thing to national security.

Keep in mind that a sizable research program on possible defense against nuclear-missile attack has been going on for years before Reagan ever took the oath of office. And properly so.

The 1972 ABM treaty drastically limited the actual deployment of anti-ballistic missile systems by the United States and the Soviet Union. But neither side has been willing to run the risk of being caught flat-footed if the other suddenly scrapped the treaty and began to deploy an ABM system in order to tip the nuclear balance.

So both great powers have continued to do research-and-development work on missile-defense systems. Such activities do not violate the 1972 treaty.

Considering that the Soviets have begun to do things that bend if they do not break the treaty, no one should have blamed Reagan if he had announced an acceleration of the R&D program on ballistic-missile defense and warned the Russians to abide by the ABM agreement. But he went further.

In his March, 1983, speech on the subject, the President conjured up the vision of an America—and ultimately of a world—free of the threat of nuclear destruction. In his words, a strategic defense program could give us the means of rendering . . . nuclear weapons impotent and obsolete."

If the English language means anything, the President was clearly holding out the prospect of a missile-defense system capable of protecting American cities from nuclear destruction in event of a large-scale missile attack.

Weinberger reinforced that impression when he described the Administration's goal as "a thoroughly reliable and total" defense against nuclear missiles.

Any President must feel cold chills at the thought that, as things stand, this country's only defense against missile attack that would kill tens of millions of Americans is the threat to kill tens of millions of Russians in return. The idea of a missile-defense system that would not hold a protective umbrella over our heads should be alluring to us all, not just to the President.

The problem is that in order to protect cities from attack an ABM system must be nearly perfect. If even a small proportion of the Soviet Union's 9,000 strategic nuclear warheads got through, millions of Americans would die. And almost nobody, even among the most enthusiastic proponents, believes that achievements of a leakproof system is likely.

Any serious effort to build such a system, rather than merely to conduct research and development as an insurance policy against a Soviet abrogation of the ABM treaty, will be enormously expensive.

The Pentagon estimates that it will require an expenditure of $26 billion over a five-year period to explore alternative technologies and to enable whoever is President in the early 1990s to decide whether an actual missile-defense system should be built.

If the answer is yes, the ultimate price tag is anybody's guess. Estimates run as high as half a trillion dollars—this for a program that, according to most knowledgeable defense scientists in and out of government, couldn't be relied on to save the American people from nuclear destruction, anyway.

Given a large enough development effort, there is a better chance of developing a system that would stop, say, 40% or 50% of incoming warheads aimed at this country's land-based strategic missiles. That wouldn't protect the populace, but it might introduce enough uncertainty into Soviet calculations to keep the Kremlin deterred from any thought of a surprise attack.

This more limited objective is in fact the most that most of Reagan's own advisers think is possible. But even here there is a downside.

To begin with, the Soviets might try to offset the effectiveness of such a missile-silo protection system by building more missiles which they could do more cheaply than we could improve the ABM system. They could also place more emphasis on submarine-launched cruise missiles that could be countered only by an expensive U.S. air-defense network that does not now exist.

Obviously such a train of events would be inconsistent with the stated U.S. goal in the strategic-arms negotiations, which is to bring about a reduction in numbers of warheads on both sides.

Beyond that, as Weinberger was reminded by this country's allies again last week talk of a limited ABM system disturbs the Europeans on grounds that (1) it smacks of an American attempt to avoid the consequences of a nuclear war in Europe, and, (2) by ensuring that the Soviets would build a comprehensive ABM system of their own, it could erode or destroy the deterrent value of the independent French and British nuclear forces.

Again, Reagan could simply have asked Congress for more money to pursue our expanded research-and-development program as a hedge against Soviet abrogation of the ABM treaty and let it go at that. After all, by the Administration's own optimistic timetable, we are talking about a weapon system that wouldn't be ready before the 21st Century.

By talking prematurely and unnecessarily in terms of changing this country's entire strategy in a way that could introduce new instabilities into the balance of terror, he has done a disservice to himself and to true national security.

[From the Los Angeles Times, Mar. 29, 1984]

LET'S USE CAUTION ON "STARS WARS"

A U.S. MONOPOLY IN SPACE TECHNOLOGY WOULD NOT LAST LONG

(By A. Fenner Milton)

For 20 years we and the soviets have been naked before each other's nuclear arsenals. If the new Soviet party chief, Konstantin U. Chernenko, pushed the button, 8,000 nuclear warheads could rain down on America in 30 minutes—and we couldn't stop a single one. Our only option would be retaliation with our own warheads.

The very fact that we both lie open to massive nuclear assault is one reason nobody has pushed the button. Deterrence has served us well. But will it work forever? This is the first question to ask in any consideration of space-based defense against intercontinental ballistic missiles.

A year ago President Reagan offered us a vision of a different world. In his so-called "Star Wars" speech he told us that he was betting on technology to save America from nuclear war. In effect he told scientists that "you gave us nuclear weapons, now make them go away," and called for a national commitment to develop a defense against ballistic missiles.

Spurred by the President's speech, the Pentagon studied the question of whether space-based systems can accomplish this mission, and its findings are embodied in the $24-billion Strategic Defense Initiative now before Congress. The point of this research-and-development package is merely to permit an informed decision in the early 1990s on whether to go ahead with "an engineering validation phase"—i.e., building real hardware. This package is only a small first step on the very long path toward a meaningful defense of our cities.

The path is long and uncertain because such a defense must deal with all vehicles that could deliver nuclear warheads. Also, the offensive side can use a whole bag of tricks to make defense more difficult. But, given our current vulnerability, no one can deny the appeal of the President's long-term goal of "rendering nuclear weapons impotent and obsolete." In fact, the goal is made even more attractive politically by recent progress with techniques that can shoot down missiles in flight without using nuclear explosives.

There may be useful intermediate steps on the path to an effective population defense. Silo defense may be the most cost-effective way to be sure that our land-based missiles will survive. Even an imperfect defense of our command and communication systems could introduce enough uncertainty to make a first strike against them unattractive. And a defense of cities that would never stop a massive Soviet attack could protect them against accidental launches or third-party attacks.

However, there are pitfalls. Given the number of warheads on each side, defensive systems that could really save our cities may prove impossible at any price. What does it mean for a missile defense of our population to "work"—when only 1% of the warheads get through it? That's about 80 cities that you can write off. Then the defensive systems themselves need protection or they will be sitting ducks. And consider the fact that satellites might prove to be tempting targets for war in space. Even a poor ballistic missile defense system can be a good anti-satellite weapon.

Without firm controls on offensive forces, the deployment of any form of defense of large parts of the United States would undoubtedly accelerate the arms race. According to the orthodox U.S. view of deterrence, nothing could be more threatening than a combination of counterforce missiles and population defense. The first strike destroys most of the enemy's forces; defense takes care of the rest. As the defensive system is being built, the other side will take steps to preserve its ability to retaliate.

Each side's uncertainty about the effectiveness of the other's defenses will also fuel the arms race. Each will assume that the other has a working defensive umbrella, and each will spend billions looking for ways to puncture it.

The 1972 anti-ballistic missile treaty, which prohibits or severely limits deployment of all forms of ballistic missile defense, was designed to remove this uncertainty. If we move ahead with developing a missile defense system, we will eventually have to renegotiate the treaty or violate it. Abrogating it would set a dangerous precedent. If we are ever to arrive at an affordable and effective defensive posture, we will need to negotiate more extensive offensive force reductions than have been seriously considered so far.

In the short run we may have little choice but to proceed with research and development. The Soviets have demonstrated a growing lack of respect for the ABM treaty, having deployed a tracking radar with an ambiuous mission at Krasnoyarsk. If they deploy an extensive system in violation of the treaty, we would be forced to follow suit. Demonstrating out technical prowess now might give the Soviets an incentive to pull back from a unilateral treaty abrogation.

But in the long run we must proceed with care. No matter how great an advantage in space technology we could gain with an accelerated R&D program, we cannot assume that a U.S. monoploy could last long. It never has with any other system. We should proceed with one foot ready to brake and a watchful eye on problems associated with transition to a defense-dominated strategy. The important decisions on ballistic missile defense, which will involve unprecedented development costs and critical arms-control issues, will not come before the early 1990s. But the debate should start now, to ensure that a rational policy is not overwhelmed by events.

[From the Washington Post, Apr. 11, 1984]

"Killer Satellites" Seen Shielding America, Not Europe—Bonn Worried by U.S. Plans for Space Weaponry

(By William Drozdiak)

Bonn, April 10.—The West German government is becoming increasingly worried that the Reagan administration's plans to explore the possibility of an antimissile defense system in outer space will cast new doubts on U.S. nuclear guarantees for the defense of Europe.

West German officials have expressed deep concern that Washington has virtually ruled out chances for a future accord with the Soviet Union that would ban space weaponry or "killer satellites."

The prospect that the United States will push ahead with research and eventual production of such arms, they said, could portend another agonizing debate about the nuclear protection of Europe only months after the controversial deployment in Western Europe of the first Pershing II and cruise nuclear missiles.

During last week's meeting of the North Atlantic Treaty Organization's nuclear planning group in Turkey, European defense ministers reportedly sharply questioned U.S. Defense Secretary Caspar W. Weinberger about whether "killer satelites" that might shield the United States from intercontinental missiles fired by the Soviet Union would leave Western Europe unprotected.

They suggested that the U.S. shield would create zones of unequal nuclear security within the alliance and lead to the "decoupling" of Europe from America, since

the United States would no longer be putting its cities at risk to defend Europe from nuclear attack.

Weinberger reportedly sought to assure his European counterparts that it was technically feasible to build antitactical missiles that would protect Europe. He also was quoted as promising close consultations with the allies concerning the development stages of space weapons and any impact on the antiballistic missile treaty with the Soviet Union.

Weinberger argued that the United States needed to catch up with the Soviets in antimissile research, but he reportedly failed to alleviate skepticism among the European delegations.

"We got the impression that the administration has made up its mind on producing these weapons and is not thinking about arms control first," a West German official said.

On his return from Turkey, West German Defense Minister Manfred Woerner openly expressed concern that the U.S. effort to develop antimissile systems in space could "destabilize the East-West balance" and increase tensions with Moscow.

He strongly endorsed early arms control agreements between the two superpowers governing all space-based weaponry. "It is in the interests of all mankind that [the U.S. program] does not open up a new dimension of the arms race," he said.

While Woerner acknowledges that the United States may need to match Soviet research, he and other West German politicians have warned about the dangers of proceeding with the production of space weapons.

Franz-Josef Strauss, who heads the Christian Social Union, a sister party of Chancellor Helmut Kohl's Christian Democrats, cited the U.S. space weapons program as evidence that the U.S.-European partnership in nuclear security "is no longer functioning."

Karsten Voigt, the foreign policy spokesman of the opposition Social Democrats, predicted today that if Washington proceeds with plans to develop space weapons, the conflict between West German and U.S. interests would set off a storm of protests. He urged Kohl to express his concern to President Reagan about the risks of an arms race in space.

The Christian Democrats anounced today that they will form a committee to study the impact that the U.S. space weapons program may have on Europe's security. Willy Wimmer, a party spokesman, said a primary purpose would be to determine if the protection of West Germany could be assured once antimissile systems were deployed in space.

Since returning from Washington last month, Kohl has abandoned his fruitless calls for a revival of detente through a meeting between Reagan and Soviet leader Konstantin Chernenko.

Bonn has been pressing for more accommodating western proposals in the Vienna talks on troop reductions in Europe as well as the Geneva negotiations for a ban on chemical weapons, but so far with little effect.

Space weapons development, however, is seen as a volatile field with critical consequences for West German and European security. "This is one area where we cannot afford to sit back and keep quiet," a West German diplomat said.

Senator PRESSLER. Good afternoon.

Let me say to our last panel, thank you for waiting. I hope we have not caused you a major personal time disruption. This subject is of such complexity and importance that I desired to go forward step by step, to get the issues on the record in preparation for the Senate floor debate. It is very necessary to have this information put forward accurately.

So with that, I call on Dr. John H. Gibbons, Director of the Office of Technological Assessment.

Again, if you can summarize as much as possible, I would very much appreciate it. Your entire statement will be placed in the record.

Dr. Gibbons.

STATEMENT OF DR. JOHN H. GIBBONS, DIRECTOR, OFFICE OF TECHNOLOGY ASSESSMENT, ACCOMPANIED BY DR. ASHTON B. CARTER, OFFICE OF TECHNOLOGY ASSESSMENT CONSULTANT, MIT; AND DR. PETER SHARFMAN, PROGRAM MANAGER, OFFICE OF TECHNOLOGY ASSESSMENT

Mr. GIBBONS. Thank you, Mr. Chairman.

As you know, my testimony today will largely be based on the background paper which we prepared for you and which is being released by your committee.

Senator PRESSLER. Yes. We thank you very much. I found that a very interesting and useful study. I would also say that I want to thank OTA for the fine space arms workshop, conducted at my request. I attended parts of the January workshop and had staff present at all times. I hope we will soon be able to release a study based upon that particular set of meetings.

Mr. GIBBONS. Yes, sir, we are in the final stage of review of that document and will be delivering it to you very shortly.

Senator PRESSLER. Great.

Mr. GIBBONS. I am accompanied by Dr. Peter Sharfman who directs our program at OTA that includes this work, and by the author of this paper, Dr. Ashton Carter from MIT, who is on my right.

As you are aware, Mr. Chairman, we embarked just a month ago on a broader, more comprehensive assessment of the new ballistic missile defense technologies in response to your request and to a similar request from the House Armed Services Committee. This larger project will use this background paper that we are discussing today as one of our starting points.

The heart of this background paper, which is what I want to focus on today, has to do with the first phase of intercept, called the boost phase intercept. As you heard this morning, all of this action occurs roughly within the first 2 to 5 minutes of the flight of a missile taking off from the Soviet Union.

On page 10 of our background paper, there is a table 2.1 which describes the kinds of missiles and the kinds of flight times that are involved, and you may wish to insert that table in the record for information.

Senator PRESSLER. What page is that on?

Mr. GIBBONS. It is on page 10.

Senator PRESSLER. Page 10.

Mr. GIBBONS. Mr. Chairman, when we review the new technologies that are contained in this whole argument, our paper supports four major technical judgments, and I would like to review those briefly with you and then summarize the findings of the document.

The first judgment is that boost phase ballistic missile defense requires very substantial advances in several very challenging areas of technology. Extensive research is going to be required to know whether these concepts would ever be made to work, much less to estimate accurately when they might be available and how much they might cost. We know at this point that the laws of nature don't forbid the kinds of directed energy weapons and adaptive optics and nuclear power sources that are talked about,

but the laws of nature do not mean that any of these systems can actually be built by man to achieve a significant portion of their theoretical potential or that this could be done relatively soon, or at an affordable cost.

A few of the exotic technologies that are being discussed, notably, the chemical lasers, have gotten beyond the proof of principle stage, but even there it would still be necessary to make the hardware work with enormously higher power than at present, and with far greater precision out in the environment of space than we have ever achieved in the laboratory.

The second of the four major technical judgments is as follows: Even if we were to develop successfully each of the individual technologies to the level needed for ballistic missile defense, putting all of these individual pieces together into a workable and dependable system would be a still more difficult task. It would be at this point that we would have to face the tremendous problems of affordable costs, survivability against very plausible Soviet efforts to attack our defensive system, and the effectiveness in the face of Soviet countermeasures designed to allow their weapons to evade or to survive our attack on them.

Now, it is sometimes helpful to use specific illustrations, and so I want this afternoon to spend just a couple minutes on a specific analysis of one particular kind of technology. I will do this in order to try to distinguish the real from the world of the ideal.

So let me illustrate the points I want to make by referring to just one of these technologies, that is, an X-ray laser powered by a nuclear explosive. Since X-rays will not penetrate very far into the atmosphere, the laser would have to be used during the period of about 1 to 3 minutes after the Soviet ICBM has emerged from the lower atmosphere but before it has deployed its warheads from the so-called bus. Since X-rays travel with the speed of light, this would be possible if the laser can be in the right place at the right time. Unfortunately, getting the laser to the right place at the right time may be more difficult than learning how to build the laser in the first place.

If the X-ray laser were placed out in geosynchronous orbit—and I remind you that out there the laser would seemingly hang right over top of the Soviet missile fields and have no speed relative to those missile fields but it would have to fire from a distance of about 40,000 kilometers. Since the X-ray beam spreads apart with increasing distance, at the 40,000 kilometer range, it would require an extremely powerful laser to be bright enough to damage the ICBM as it came out of the atmosphere. In fact, each laser operating at that kind of a range would require its own thermonuclear bomb to power it. It would be a very massive, one-shot affair, because you would have to go so far away from the surface of the Earth to be able to hang up there in the sky.

Hence, we would need one satellite, one thermonuclear bomb, and a laser to go with it for every Soviet missile that we wish to attack, and that would probably be prohibitively expensive.

Well, the obvious answer to that problem is to shorten the range by moving to lower orbit, and indeed, if the laser could fire on the ICBM at a range, say, of only a few thousand kilometers instead of 40,000 kilometers, a single satellite with a nuclear explosive might

power many lasers: One explosive suddenly bursting a number of lasers, each pointed at a different ICBM coming up out of the atmosphere. Hence, we might need only a fraction of the number of satellites and orbiting bombs compared with geosynchronous orbit.

Unfortunately, if the satellites are placed in this low orbit, they move very rapidly with respect to a position on the ground. You can sometimes see a low-orbiting satellite from here in Washington, and you can see it move right across the sky rather quickly.

We would therefore need many satellites and many lasers in orbit around the globe in order to assure that at least one of them was in position at the right moment when the Soviets launched their ICBM's. And this chart gives some indication of the numbers of satellites in low orbit that would be required to cover the missile fields. Furthermore, such satellites in low orbit might be quite vulnerable to a precursor Soviet attack on the satellites themselves just before the Soviets launched their ICBM's.

That leads some analysts to propose a so-called popup system that I believe Senator Glenn spoke of this morning. In that case, a U.S. missile on the ground or in a submarine would fire and X-ray laser system up on its own rocket into position, immediately after receiving word that the Soviet ICBM had been launched.

This method would enable us to use fewer than one nuclear bomb in space per Soviet ICBM and would also eliminate the problem of Soviet attack on our orbiting lasers as a precursor attack. However, as you can see from the figure that Dr. Sharfman now will show, the geometry involved would require either an extraordinarily fast defensive booster, for instance, a rocket many more times more powerful than the Saturn V, simply because if one backs off from the Soviet Union, that line of lowest altitude of fire gets higher and higher in the atmosphere and you would have to take longer and longer to get up there. Alternatively it would require getting in very close, for example, firing the popup system from a submarine right off the Soviet coast that somehow survived Soviet attacks on it while maintaining constant communications with our orbital sensors that in turn would tell the submarine where and when to fire.

In short, when one begins to think about the particulars, developing an X-ray laser, even one approaching theoretical limits of power and narrowness of beam, would not be the solution to the problem; rather, it would meet only one of many requirements attendant to solving the probem.

The third of the four major technical judgments, Mr. Chairman, is that it appears extremely unlikely that it will be possible to construct a ballistic missile defense system that is so good that it could defend our population and our industry against an all-out Soviet attack. A major issue in thinking about ballistic missile defense is whether our purpose is to strengthen deterrence by strengthening our strategic military posture, or whether our objective is not only to strengthen deterrence, but also to render the Soviets incapable of destroying our society with nuclear missiles, even if deterrence fails.

In the former case, there is room for debate about whether a major ballistic missile defense program is sensible, because as a matter of principle, it is not necessary for a defense system to be

nearly perfect in order to have some value. But in the latter case, if we wish to shield our cities against an all-out attack directed against them, we need a nearly perfect defense because many people can be killed with a very few weapons; and the criteria for an acceptable system are therefore much, much tougher.

To meet the stringent criterion of shielding cities against an all-out attack, the defense would have to be enormously larger and more expensive than the offense would have to be.

Section 7 of the OTA background paper explains some of the reasons for this. They include boost phase defenses that would have to be very large in order to assure that at least one satellite was in the right place at the right time. Midcourse defenses would have to be very large to deal with decoys that travel in the vacuum outside the atmosphere, and terminal defenses would have to be very large in order to protect a large number of possible targets within the United States if indeed we are trying to defend large areas of our continent rather than a few particular sites.

The table before you, table 7-1, displays the size of the force that might be needed to deal with a plausible future Soviet force, a force, incidentally, no larger than their present force but equipped with solid fueled missiles like the U.S. Peacekeeper—MX—missile, in order to accelerate more rapidly during that boost phase.

If the U.S. built such a force, and if the Soviets responded by increasing the size of their force in order to saturate our defenses, which would be likely, the cost to the Soviets of doubling their hypothetical force would be far less than the cost to us of doubling our defensive forces in order to thwart them.

Since this is a quite striking result, I would like to call to your attention that the overwhelming preponderance of informed opinion agrees that a defense capable of making nuclear ICBM's impotent lies far into the future, if, in fact, it can ever be obtained. Indeed, I would venture to say that the prospects of such capabilities are so remote that research and development today, although possibly helpful in developing a less than perfect system which could defend military targets or defend civilian targets against small attacks, is essentially irrelevant to pursuing the goal of making nuclear ICBM's obsolete.

The fourth finding, Mr. Chairman, is as follows: ballistic missile defense with more modest goals, that is, of enhancing our military posture in some way short of rendering ICBM's obsolete, is difficult to evaluate at this point in time. There is room for controversy over how to formulate our technical goals, and there is enormous uncertainty about whether the technologies now proposed for research can be developed to the point of meeting any of the goals that have been proposed. Our background paper lists some of the goals which have been proposed, and it explains briefly why they are controversial, but we do not venture a judgment about the likelihood or cost of attaining any of them.

It is clear that a research program such as the one which the Defense Department has proposed, would, over time, reduce many of these uncertainties. However, at this point, it is also clear that a major research program would also have a number of significant side effects, some of which could be destabilizing, apart from being quite expensive.

Mr. Chairman, we are far from being able to make definitive judgments about a ballistic missile defense program which pursues goals that are more modest than the area defense of American cities against an all-out attack. We do not know yet what these more modest goals should be, and we do not know whether it would be possible, much less affordable, to attain them. These are matters about which our full scale assessment, we trust, will enable us to provide you in the near future with some more information.

At the very last of our written testimony on page 11 to page 15, we summarize some of the broader judgments that can be derived, which the background paper does support, and I might just read the first sentence of each of those nine to underscore them, Mr. Chairman, if that is acceptable to you.

Senator PRESSLER. Without objection.

Mr. GIBBONS. First, the prospect that emerging so-called star wars technologies, when further developed, will provide a perfect or even a near-perfect defense system, literally removing from the hands of the Soviet Union the ability to do socially mortal damage to the United States with nuclear weapons, is so remote that it should not serve as the basis of public expectation or national policy about ballistic missile defense.

Second, the wisdom of deploying a less than perfect ballistic missile defense remains controversial.

Third, the strategic goal of President Reagan's Strategic Defense Initiative which calls for emphasized BMD research, perfect, near-perfect, or less-than-perfect defense against ballistic missiles, remains unclear.

Fourth, in all cases, directed energy weapons and other devices with the specifications needed for boost phase intercept of ICBM's have not yet been built in the laboratory, much less in a form suitable for incorporation in working defense system.

Fifth, moreover, making the technological devices to perform the needed specifications in a controlled situation is certainly not the crux of the technical challenge facing designers of an effective ballistic missile defense. A distinct challenge is to fashion from these devices some reliable defense architecture, taking into account the vulnerability of the defense components, the susceptibility to future Soviet countermeasures, and costs relative to those countermeasures.

Sixth, it seems inevitable that potent, directed energy weapons will be developed for other military purposes, even if such weapons are never incorporated into effective BMD's.

Seventh, for modest defensive goals requiring less than perfect performance, traditional reentry phase defenses and/or more advanced midcourse defenses might suffice to the job.

Eighth, deployment of missile defenses based on new technologies is forbidden by the Anti-Ballistic Missile Treaty reached at SALT I.

And finally, Mr. Chairman, there is a close connection that is not explored in detail in this background paper but a very close connection, and an important one, between advanced BMD concepts and future antisatellite or so-called ASAT systems.

Mr. Chairman, that concludes a summary of the testimony we have provided to you.

Dr. SHARFMAN, Dr. Carter and myself will be pleased to respond to any questions you might have.

[Mr. Gibbons' prepared statement follows:]

Statement of Dr. John H. Gibbons
Director
Office of Technology Assessment
to the
Senate Committee on Foreign Relations

April 25, 1984

NEW TECHNOLOGIES FOR DEFENSE AGAINST STRATEGIC BALLISTIC MISSILES

I am pleased to testify today on some of the critical technological issues involved in the President's proposed strategic defense initiative (SDI). My testimony today is based primarily on a background paper entitled Directed Energy Missile Defense in Space, which OTA has had prepared and which this Committee is releasing today. I am accompanied by Dr. Ashton Carter of M.I.T., the author of this background paper, and by Dr. Peter Sharfman, OTA's Program Manager for International Security and Commerce.

Let me begin with a word or two about this background paper. A year ago, after the President's March 23 speech, OTA received a number of Congressional inquiries about the new technologies that were said to underlie the new policy initiative. As we began to look into this matter, we saw a need for a primer on the newer technologies proposed, especially those involving the use of directed energy weapons in space. The main purpose of such a primer would be to prepare OTA to respond intelligently and helpfully to requests for more detailed analyses. Accordingly, we commissioned a background paper from Dr. Ashton Carter, a former member of our staff who had worked on ballistic missile defense among other subjects. Dr. Carter subsequently worked on strategic systems for

the Director of Program Analysis and Evaluation in the Office of the Secretary of Defense before assuming his present position at the Center for International Studies of M.I.T.. When Dr. Carter's work was about half completed, we received a request from Senators Pressler and Tsongas for a paper which could serve to provide technological background to this Committee. Dr. Carter's work was directly pertinent, and I am pleased to make it available for your use.

I should make it clear at the outset that this background paper does not attempt a full treatment of the subject of strategic defense, or of all the technological, strategic, and political issues surrounding the SDI. Its purpose is to introduce the reader to some of the more exotic technologies that have been proposed and to the kinds of problems which we would confront if we were to attempt to move these technologies from concept to deployed weapon. We hope that the considerations raised in this paper would also be useful in evaluating whatever technologies may be advanced in the future in this rapidly-moving field. This background paper is, in short, not a full-fledged technology assessment, but an introduction to an unfamiliar class of potential new technologies. Unlike our full-fledged technology assessments, its release has not been approved by the Technology Assessment Board.

As you are aware, Mr. Chairman, OTA embarked last month on a full-fledged assessment of "New Ballistic Missile Defense Technologies," in response to your request and to a similar request from the House Armed Services Committee. We expect that new project to use this paper, along with the product of our recent workshop on

arms control in space, as a starting point for the larger effort.

This background paper on which my testimony today is based has received extensive review both inside and outside OTA, and we are confident that it can serve as a reliable introduction not only to the proposed technologies for directed energy missile defense in space, but also to the broader issues of how deployment of such technologies might affect our overall national security.

The heart of OTA's background paper is an analysis of the problem of intercepting ICBMs in their boost phase. This is the concept of attacking a Soviet ICBM while its rockets are still firing to propel it on to its ballistic trajectory -- in other words, during the first two to five minutes of its flight. From a conceptual point of view, there are several major advantages to boost-phase intercept: (1) a large rocket motor firing at full power is an easily detected and tracked target; (2) a missile is more vulnerable than the RVs (re-entry vehicles) which it releases after the boost phase is completed; (3) there are fewer targets to attack before the RVs (6, 10, or more per missile) separate from the missile itself.

However, there are some major disadvantages to boost phase intercept: there is very little time in which to carry it out after the Soviet missile is fired, and it must be carried out from space over Soviet territory. The short time requires having weapons "in position" in advance, and being able to make critical decisions almost instantly; being in space over Soviet territory raises the possibility of a precursor Soviet attack aiming to "punch a hole" in the defense to let the ICBMs through. Most analysts of boost phase

intercept see it as a part of a "layered defense," in which Soviet missiles which escaped the boost-phase defensive system (layer one) would be further engaged by a "mid-course" system (layer two) and those which survived to re-enter the atmosphere would be again engaged by a so-called terminal defense (layer three).

After an introductory section, the background paper reviews the characteristics of the ICBM boosters which the systems to be researched under the SDI would be intended to attack. This is followed by a relatively long section 3 which introduces the reader to the novel technologies identified by the "Fletcher Commission" as worth pursuing -- technologies thought to offer some possibility of being able to destroy large numbers of Soviet ICBMs during boost phase. Section 4 reviews the other essential elements of a deployed weapons system: besides the kill mechanism, we would need systems to determine that a Soviet attack was under way and still allow a timely decision to shoot at the enemy missiles; systems to find the target, track the target, aim the weapon, and fire; and systems to confirm a "kill" so that the overall system can safely move on to attack the next target. In addition, we would require systems to defend against attacks on the defensive system itself, and to provide power for the whole system. Taken as a whole these tasks are certainly at least as difficult to accomplish as simply developing an effective kill mechanism. Section 5 sketches the nature and potential effectiveness of a variety of possible Soviet countermeasures. The following section discusses the relationship between "old" ballistic missile defense technologies that the U.S. has been working on for years, and the "new" ballistic missile

defense technologies receiving so much recent attention.

To illustrate the kinds of system architecture which people currently have in mind, section 7 describes the major elements of a hypothetical system in order to show how all of these technologies would have to fit together in a system, and the magnitude of a system designed to fire at a plausible future Soviet ICBM force during its boost phase. This hypothetical case makes many assumptions about matters which cannot yet be calculated in precise detail; it describes not a real system but the kind of system now being discussed. If the U.S. ever reaches the stage of deploying a large ballistic missile defense system, that system will undoubtedly differ in many respects from this illustration. Nevertheless, this illustrative example makes evident one of the reasons why the overwhelming preponderance of expert opinion holds that such a comprehensive (or "perfect") defense would not be feasible in the foreseeable future, for both technical and economic reasons. Consequently, the next two sections address in some detail the different requirements and implications of a "perfect defense" and of a "less-than-perfect" defense. The final section of the background paper, containing its judgements and observations, is reproduced at the end of this testimony.

Mr. Chairman, the review of new technologies contained in this background paper supports four major technical judgements:

1. Boost-phase ballistic missile defense requires very substantial advances in several very challenging areas of technology. We would have to do extensive research to know whether these concepts could ever be made to work, much less estimate

accurately when they would be available and how much they would cost. The laws of nature do not forbid the kinds of directed energy weapons, adaptive optics, and nuclear power sources that are talked about for the SDI, but that does not mean that any of these systems can actually be built to achieve a significant portion of its theoretical potential, or that this could be done releatively soon, or at an affordable cost. A few of the exotic technologies -- notably chemical lasers -- have progressed beyond the "proof-of-principle" stage, but it would still be necessary to make the hardware work with enormously higher power and far greater precision in space than we have yet achieved in the laboratory. Most of the exotic technologies are at the stage where we cannot tell yet whether their fruition would be 5 years in the future, 20 years in the future, or never. It is instructive to recall that thirty years ago the U.S. government was spending research money on both high-speed computers and nuclear-powered aircraft. History shows that one of these was a good idea, and one was not.

2. *Even if we were to develop successfully each of the individual technologies to the level needed for ballistic missile defense, putting them all together into a workable system would be a still more difficult task.* It would be at this point that we would have to face tremendous problems of *affordable cost, survivability* against plausible Soviet efforts to attack our defensive system, and effectiveness in the face of *Soviet countermeasures* designed to allow their ICBMs to evade or survive our attack on them.

Let me illustrate these points by referring to just one of the possible technologies reviewed in section 3 of the background paper: an X-ray laser powered by a nuclear explosive. Since X-rays will not penetrate very far into the atmosphere, the laser would have to be used during the period of one to three minutes after the Soviet ICBM has emerged from the atmosphere but before it has deployed its MIRVs. Since X-rays travel at the speed of light, this would be possible <u>if</u> the laser could be in the right place at the right time. Unfortunately, getting the laser to the right place at the right time may be more difficult than learning how to build such a laser in the first place.

If the X-ray laser were placed in geosynchronous orbit over the Soviet missile silo, it would have to fire at a range of around 40,000 km. Since the X-ray beam spreads apart with increasing distance, at a 40,000 km range (figure 3.8) it would require an extremely powerful laser to be bright enough at a single point to damage an ICBM -- in fact, each laser operating at that range would require its own thermonuclear bomb to power it. Hence we would need one satellite, one bomb, and one laser for each Soviet missile we wished to attack, which would be prohibitively expensive.

The obvious answer to this problem is to shorten the range by moving to a lower orbit, and indeed if the laser could fire on the ICBM at a range of a few thousand km., a single nuclear explosive could power many lasers. Hence we would need only a fraction as many satellites and orbiting bombs. Unfortunately, if the satellites are in a low orbit, they move rapidly in relation to a point on the ground, and we would therefore need many satellites and

lasers in orbit around the globe in order to ensure that one of them was in position at the exact moment the Soviets launched their ICBMs. (See figure 3.5) Furthermore, such satellites in low orbit might be quite vulnerable to a precursor Soviet attack on the satellites themselves just before launching the ICBMs.

This has led some analysts to propose a so-called "pop-up" system in which a U.S. missile on the ground (or in a submarine) would fire the X-ray laser system into position immediately after receiving word that Soviet ICBMs had launched. This would enable us to use fewer than one nuclear bomb in space per Soviet ICBM, and would also eliminate the problem of Soviet attack on our orbital lasers immediately before they fired their ICBMs. However, as figure 3.9 shows, the geometry involved would require either an extremely fast defensive booster (an enormous system many times more powerful than the Saturn V that launched Apollo to the moon), or getting in very close -- for example a submarine right off the Soviet coast that somehow survived Soviet attacks on it while maintaining constant communications with our orbital sensors that would tell the submarine when and where to fire.

In short, developing an X-ray laser -- even one approaching the theoretical limits of power and narrowness of beam -- would not be the solution of the problem.

3. It appears extremely unlikely that it will be possible to construct a ballistic missile defense system so good that it could defend American cities -- our population and our industry -- against an all-out Soviet attack. A major issue in thinking about ballistic missile defense is whether our purpose is to strengthen deterrence

by strengthening our strategic military posture, or whether our objective is not only to strengthen deterrence but also to render the Soviets incapable of destroying our society with nuclear missiles even if deterrence fails. In the former case, there is room for debate about whether a major ballistic missile defense program is sensible, because as a matter of principle it is not necessary for a defense to be nearly perfect in order to have value. In the latter case, if we wish to shield our cities against an all-out attack directed against them, we need a nearly-perfect defense, because many people can be killed with very few weapons, and the criteria for an acceptable system are therefore much tougher.

To meet the stringent criterion of city defense against an all-out attack, given the theoretically plausible capabilities of the technologies considered by the Fletcher Commission, the defense would have to be enormously larger and more expensive than the offense. Section 7 of the background paper explains some of the reasons: boost-phase defenses would have to be very large in order to ensure that at least one satellite was in the right place at the right time; mid-course defenses would have to be very large to deal with decoys, and terminal defenses would have to be very large to protect a large number of possible targets within the U.S.. Table 7.1 displays the size of the force we would need to deal with a plausible future Soviet force -- one no larger than their present force, but equipped with solid-fuel missiles like the U.S. "Peacekeeper" (MX) missile in order to accelerate more rapidly during boost phase. If the U.S. built such a force and the Soviets

responded by increasing the size of their forces in order to saturate our defenses, *the cost to the Soviets of doubling their hypothetical force would be far less than the cost to us of doubling our defensive force in order to thwart them.*

Since this is quite a striking result, I call to your attention that the overwhelming preponderance of informed opinion agrees that a defense capable of making nuclear ICBMs impotent lies far in the future, if ever. Indeed, I would venture to say that the prospects of such capabilities are so remote that research and development today, although possibly helpful in developing a less-than-perfect system for defending military targets or defending civilian targets against small attacks, is essentially irrelevant to pursuing the goal of making nuclear ICBMs obsolete. This would seem to support the judgement that *arguments about the desirability of supplanting mutual assured destruction with a national security posture based on defense, however philosophically attractive, are irrelevant to the choices to be made in the near future.*

4. *Ballistic missile defense with more modest goals -- that is, enhancing our military posture in some way without rendering ICBMs obsolete -- is difficult to evaluate.* There is room for controversy over how to formulate our technical goals, and there is enormous uncertainty about whether the technologies now proposed for research can be developed to the point of meeting any of the goals proposed. The background paper lists some of the goals which have been proposed, and explains briefly why they are controversial, but does not venture a judgement about the liklihood, or cost, of attaining any of them. It is clear that a research program such as

the one which the Defense Department has proposed in response to the President's strategic defense initiative would, over time, reduce many of these uncertainties. However, it is also clear that ***a major research program would also have a number of significant side effects, some of which could be destabilizing, apart from being quite expensive.***

Mr. Chairman, we are far from being able to make definitive judgements about a ballistic missile defense program which pursues goals more modest than defense of cities against all-out attack. We do not know what these more modest goals should be, and we do not know whether it would be possible, much less affordable, to attain them. These are matters which our full-scale assessment will address in some depth and detail, and we will report to you as soon as we can. Nevertheless, I wish to summarize by sharing with you those broader judgements which the background paper does support:

1. The prospect that emerging "Star Wars" technologies, when further developed, will provide a perfect or near-perfect defense system, literally removing from the hands of the Soviet Union the ability to do socially mortal damage to the United States with nuclear weapons, is so remote that it should not serve as the basis of public expectation or national policy about ballistic missile defense (BMD). This judgment appears to be the consensus among informed members of the defense technical community.

Technical prognosis for such a perfect or near-perfect defense is extremely pessimistic because of the concentration and fragility of society; because all concepts identified as candidates for a future defense of population are kown to be susceptible to countermeasures

that would permit the Soviet Union to retain a degree of penetration with their future missile arsenal despite costly attempts to improves the U.S. defense; because the Soviet Union would almost cesrtainly make such a determined effort to avoid being disarmed by a U.S. defense; and because missile defense does not address other methods for delivering nuclear weapons to the United States.

Mutual assured destruction (MAD), if this term is applied to a state of technological existence rather than to a chosen national policy, is likely to persist for the foreseeable future.

2. ***The wisdom of deploying less-than-a-perfect ballistic missile defenses remains controversial.*** Less-than-perfect defenses would still allow the Soviet Union to destroy U.S. society in a massive attack but might call into question the effectiveness of smaller, specialized nuclear strikes.

Certain theories about nuclear war maintain that such defenses could lessen the chances of nuclear war and enhance U.S. security by protecting U.S. retaliatory forces; by interdicting "limited" nuclear strikes; by further confusing Soviet predictions of the outcome of a strike; by driving Soviet missile deployments in directions favored by the United States; by lessening the consequences of nuclear attack; and/or by fulfilling still other strategic goals.

Critics dispute the validity of some of these goals; dispute that technology can fulfill the truly useful goals; and/or argue that the many harmful side effects of introducing BMD to the strategic equation and altering the Anti-Ballistic Missile (ABM) Treaty regime are not worth satisfying these goals.

To address the wisdom of less-than-perfect defense, the public and policymakers would need a precise statement of the strategic goal of the deployment, an assessment of whether technology could satisfy that goal, and an analysis balancing fulfillment of the goal against the side effects and uncertainties of introducing a new ingredient into the strategic nuclear arena.

3. ***The strategic goal of Pesident Reagan's Strategic Defense Initiative calling for emphasized BMD research -- perfect, near-perfect, or less-than-perfect defense against ballistic missiles -- remains unclear.*** No explicit technical standards or criteria are therefore available against which to measure the technologicl prospects and progress of this initiative.

4. ***In all cases, directed-energy weapons and other devices with the specifications needed for boost-phase intercept of ICBMs have not yet been built in the laboratory, much less in a form suitable for incorporation in a complete defense system.*** These devices include chemical lasers, excimer and free electron lasers, x-ray lasers, particle beams, lightweight bigh-velocity kinetic energy weapons, and microwave generators, together with tracking, aiming, and pointing mechanisms, power sources, and other essential accompaniments.

It is unknown whether or when devices with the required specifications can be built.

5. ***Moreover, making the tchnological devices perform to the needed specifications in a controlled situation is not the crux of the technical challenge facing designers of an effective ballistic missile defense. A distinct challenge is to fashion from these***

devices a reliable defensive architecture, taking into account vulnerability of the defense components, susceptibility to future Soviet countermeasures, and cost relative to those countermeasures.

New intercept mechanisms -- directed energy weapons and the like -- therefore do not by themselves necessarily herald dramatically new BMD capabilities.

6. *It is clear that potent directed-energy weapons will be developed for other military purposes, even if such weapons are never incorporated into effective BMDs.* Such weapons might have a role in nuclear offense as well as defense, in anti-satellite (ASAT) attack, in anti-aircraft attack, and in other applications of concern to nuclear policy and arms control. Defense and arms control policy will thus need to face the advent of these new weapons, irrespective of their BMD dimension.

7. *For modest defensive goals requiring less-than-perfect performance, traditional reentry phase defenses and/or more advanced mid-course defenses might suffice.* Such defenses present less technical risk than systems that incorporate a boost-phase layer, and they could probably be deployed more quickly.

New ideas for improving such "old" BMD concepts have emerged in the atmosphere of technical optimism enjoyed by the boost-phase concepts.

8. *Deployment of missile defenses based on new technologies is forbidden by the Anti-Ballistic Missile (ABM) Treaty reached at SALT 1.* The Treaty permits only restricted deployment of traditional BMDs using fixed, ground-based radars and interceptor missiles. Research into new technologies, and in selected cases development

and testing of defense systems based on these technologies, are allowed within the Treaty.

9. There is a close connection, not explored in detail in this Background Paper, between advanced BMD concepts and future anti-satellite (ASAT) systems. This connection springs from four observations: 1) ASAT attack on space-based weapons and sensors is probably the most attractive countermeasure to boost-phase BMD; 2) directed-energy weapons are more likely to succeed in the easier mission of ASAT than in the more difficult mission of boost-phase BMD; 3) to a degree dependent on technical details, early stages of development of boost phase BMDs might be conducted in the guise of ASAT development, stimulating anxieties about the health of the ABM Treaty regime; 4) to a degree dependent on technical details, concluding a treaty with the Soviet Union limiting ASAT development would impede BMD research at a earlier stage than would occur under the terms of the ABM Treaty alone.

Directed Energy Missile Defense in Space

Background Paper

April 1984

Prepared under contract for the Office of Technology Assessment

by Ashton B. Carter
Massachusetts Institute of Technology

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Preface

This background paper was prepared by Dr. Ashton B. Carter under a contract with the Office of Technology Assessment. OTA commissions and publishes such background papers from time to time in order to bring OTA up to date on technologies that are the subject of frequent congressional inquiry. After Dr. Carter's work was under way, Senators Larry Pressler and Paul Tsongas of the Senate Foreign Relations Committee requested that the resulting paper be made available to that Committee as soon as possible. OTA is issuing the paper in the belief that others in Congress and members of the public will find it of interest and importance.

An OTA background paper differs from a full-fledged technology assessment. Background papers generally support an ongoing assessment of broader scope or explore emerging technological issues to determine if they merit a fuller, more detailed assessment. On March 22, 1984, the Technology Assessment Board directed OTA to carry out a full-fledged assessment of "New Ballistic Missile Defense Technologies," for which this background paper will serve as one point of departure.

This paper was prepared for OTA's International Security and Commerce Program, under the direction of Lionel S. Johns (Assistant Director, Energy, Materials, and International Security Division) and Peter Sharfman (Program Manager).

Section 1
INTRODUCTION

This Background Paper describes and assesses current concepts for directed-energy ballistic missile defense in space. Its purpose is to provide Members of Congress, their staffs, and the public with a readable introduction to the so-called "Star Wars" technologies that some suggest might form the basis of a future nationwide defense against Soviet nuclear ballistic missiles. Since these technologies are a relatively new focus for U.S. missile defense efforts, little information about them has been readily available outside the expert community.

Directed-energy or "beam" weapons comprise chemical lasers, excimer and free electron lasers, nuclear bomb-powered x-ray lasers, neutral and charged particle beams, kinetic energy weapons, and microwave weapons. In addition to describing these devices, this Background Paper assesses the prospects for fashioning from such weapons a robust and reliable wartime defense system resistant to Soviet countermeasures. The assessment distinguishes the prospects for perfect or near-perfect protection of U.S. cities and population from the prospects that technology will achieve a modest, less-than-perfect level of performance that will nonetheless be seen by some experts as having strategic value. Though the focus is technical, the Paper also discusses, but does not assess in detail, the strategic and arms control implications of a major U.S. move to develop and deploy ballistic missile defense (BMD).[1]

This Background Paper grows indirectly out of President Reagan's celebrated television speech of March 23, 1983, in which he called for a "long-term research and development program to begin to achieve our ultimate goal of eliminating the threat posed by strategic nuclear missiles."[2] Pursuant to the President's speech, the Department of Defense established a Defensive Technologies Study Team under James C. Fletcher (of the University of Pittsburgh) to prescribe a plan for the R&D program. A parallel effort, called the Future Security Strategy Study and headed by Fred S. Hoffman (of Research and Development Associates), addressed the implications for nuclear policy of renewed emphasis on BMD. This Paper covers the same technologies and issues as these Defense Department studies. The ABM Treaty reached at SALT I[3] severely restricts the development, testing, and deployment of BMD systems. Though this Background Paper treats the strategic roles of missile defenses, including many of their arms control implications, it does not treat the vital international political implications of a major U.S. move to BMD.

Focused on directed-energy intercept of missiles in their boost phase, i.e., on "Star Wars" proper, this Paper does not analyze midcourse and reentry BMD systems or non-BMD applications of directed-energy weapons.[4] "Star Wars" efforts generally further concentrate on intercept of intercontinental ballistic missiles (ICBMs) rather than the related but somewhat different problems of intercept of submarine launched ballistic missiles (SLBMs) or intermediate-range ballistic missiles (IRBMs). This Paper is therefore not a substitute for a more complete treatment of the entire subject of BMD.[5] Moreover, BMD itself is only part of the larger subject of strategic defense, comprising defense against bombers and cruise missiles, civil defense, passive defense of military targets, anti-submarine warfare (ASW), and preemptive counterforce attack in addition to BMD.

[1] BMD is the most common of four roughly equivalent acronyms covering defense against nuclear ballistic missiles. Such defenses were formerly called anti-ballistic missile (ABM) systems, but this designation fell out of favor after the debate over and eventual demise of the Sentinel and Safeguard ABM systems in the late 1960's and early 1970's. BMD largely replaced ABM as the term of choice, but recently the more self-explanatory Defense Against Ballistic Missiles (DABM) has gained popularity. Within the Executive Branch, BMD efforts pursuant to President Reagan's so-called "Star Wars" speech are referred to as the Strategic Defense Initiative (SDI). Normally the term strategic defense comprehends other methods for limiting damage from nuclear attack besides BMD.

[2] The relevant portions of President Reagan's speech are reproduced in Appendix A.

[3] The ABM Treaty and related documents are reproduced in Appendix B.

[4] Appendix C describes briefly, but does not assess, other proposed military applications of directed-energy weapons.

[5] For a more complete treatment, see *Ballistic Missile Defense*, ed. Ashton B. Carter and David N. Schwartz (Brookings, 1984).

It is unusual for the President to express himself on, and for the Congress and public consequently to concern themselves with, long-term research and development. "Star Wars" is thus a somewhat unusual subject for a technology assessment intended for a public policy audience. It is in the nature of this subject that unknown or unspecified factors outweigh what is known or can be presented in concrete detail. Many of the technologies discussed in this Paper, and most certainly all of the schemes for fashioning a defense system from these technologies, are today only paper concepts. In the debate over the Safeguard ABM system a decade ago, or over basing modes for the MX missile in recent years, one could analyze in detail the technical properties of well-defined systems in engineering development. So vague and tentative are today's concepts for "Star Wars" BMD that a comparable level of analysis is impossible. Fashions and "front runners" are likely to change. Nonetheless, one is faced with assessing the concepts receiving attention today within the Executive Branch and which underlie the President's Strategic Defense Initiative. Fortunately, judgments deduced from generic properties of these concepts, which are unlikely to change, are sometimes telling.

This Paper is based on full access to classified information and studies performed for the Executive Branch. But it turns out that a fully adequate picture of this subject can be presented in unclassified form. One reason is that the important features of the directed-energy BMD concepts are based on well-known physics, and many have in fact been discussed for 20 years. The second reason is that at this early stage of conceptualization there is simply no point in (and little basis for) discussion at the detailed level where classified particulars make a difference. The properties of actual weapon systems in engineering development, by contrast, are normally and understandably classified.

The author and OTA wish to thank officials of the Army's Ballistic Missile Defense Systems Command (BMDSCOM), the Lawrence Livermore National Laboratory, the Los Alamos National Laboratory, the Defense Advanced Research Projects Agency (DARPA), the Sandia National Laboratory, the Air Force Weapons Laboratory (AFWL), the Office of the Secretary of Defense (OSD), and the Central Intelligence Agency (CIA) for their hospitality and cooperation. Many individuals aided the research for this Background Paper, though none shares the author's sole responsibility for errors of fact or judgment. The author and OTA wish especially to thank Hans Bethe, Richard Briggs, Al Carmichael, Albert Carnesale, Paul Chrzanowski, Robert Clem, Sidney D. Drell, Dick Fisher, John Gardner, Richard L. Garwin, Ed Gerry, Jack Kalish, Glenn A. Kent, Louis Marquet, Michael M. May, Tom Perdue, Theodore A. Postol, George Rathjens, Victor Reis, Jack Ruina, George Schneiter, David N. Schwartz, Robert Selden, Leon Sloss, Daryl Spreen, Robin Staffin, John Steinbruner, Sayre Stevens, Thomas Weaver, Stephen Weiner, and Wayne Winton.

This Background Paper contains information current as of January 1, 1984.

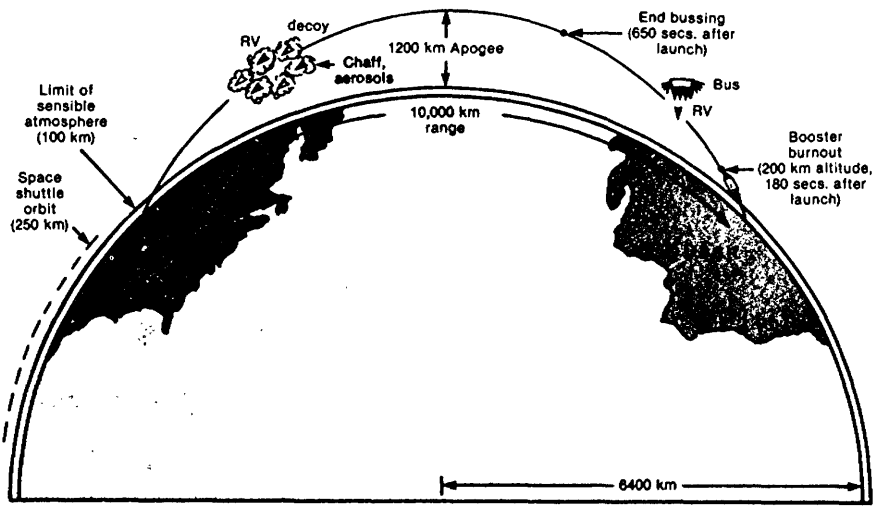
Section 2
BOOSTER CHARACTERISTICS

Intercept of ICBMs in their boost phase offers advantages and disadvantages relative to intercept of reentry vehicles (RVs) later in the trajectory. The boosters are fewer and generally more easily disrupted or destroyed than the RVs. Decoy boosters would have to match an ICBM's huge heat output, making this offensive tactic attractive only in certain circumstances. The disadvantages of boost phase intercept are that boost phase is only a few minutes long and comprises the earliest stage of an attack, and that sensing and intercept must be accomplished from outer space and over enemy territory.

Figure 2.1 shows an ordinary (minimum energy) trajectory of a hypothetical future Soviet ICBM that has been given, for illustration, the boost profile of the U.S. MX Peacekeeper. Pressure from a steam generator expells the missile from its storage cannister. Once clear of the cannister, the missile ignites its first stage motor. The first stage burns for about 55 seconds, burning out at an altitude of about 22 kilometers. The second stage also burns for 55 sec, burning out at 82 km. The third stage burns for 60 sec and carries the remainder of the missile to about 200 km, the altitude of the lowest earth orbiting satellites.

When the third stage is jettisoned at the end of the 3-minute boost phase, the remainder of the missile consists of the post-boost vehicle (PBV) or "bus" and its cargo of 10 reentry vehicles. At this point the bus and RVs are in ballistic free-fall flight to the United States. Even if they are disrupted in some way or destroyed, these objects or their debris will reenter the atmosphere over the United States. The last few seconds of third stage burn are crucial for giving the payload

Figure 2.1.—The Flight of a Hypothetical Future Soviet ICBM With the Booster Characteristics of the U.S. MX Peacekeeper, Drawn to Scale



SOURCE: Author.

enough speed to reach the United States, so disruption of boost phase any time right up to burnout will cause the warheads to fall far short.

For the next 500 seconds or so after burnout—almost until it reaches apogee—the bus uses its thrusters to make small adjustments to its trajectory. After each adjustment, it releases an RV. RVs released on different trajectories continue on to different targets as multiple independently targeted reentry vehicles (MIRVs). Decoys and other penetration aids for helping the RVs escape defenses later in the trajectory are deployed during busing.

The bus itself is a target of declining value as it dispenses its RVs. Destroying it early in the deployment process would obviously be useful: the RVs not yet deployed from the bus would still arrive at the United States, but perhaps nowhere near their intended targets. If cities are the targets, relatively small aiming errors might be inconsequential. In any event, tracking the bus to allow some form of intercept requires a different type of sensor from that which tracks the booster for boost phase intercept, since the bus's thrusters are small and operate intermittently. Because of its small size, the bus (or at least critical elements of it) might be more easily hardened against directed-energy weapons than the booster. For all these reasons, the value of attempting bus intercept is very unclear, and it usually does not figure prominently in BMD discussions.

From apogee, the slowest point in their free-fall trajectory, the RVs and empty bus gain speed as they fall back to earth. RVs are more resistant to damage from directed-energy weapons than boosters, and they might be accompanied by many decoys. When these objects enter the upper atmosphere at about 100 km altitude somewhat over 2 minutes before impact, they begin to heat up, and the lighter objects slow down. Still lower, below 50 km altitude and less than a minute before impact, the objects undergo violent deceleration and the bus breaks up. The RVs, now glowing with heat, streak toward their targets at an angle of about 23 degrees to the horizontal.

The trajectory shape can be altered at the expense of payload (see Figure 2.2). A lofted trajectory takes longer but reenters faster, and a depressed trajectory can offer unfavorable viewing angles to defensive sensors late in the trajectory.

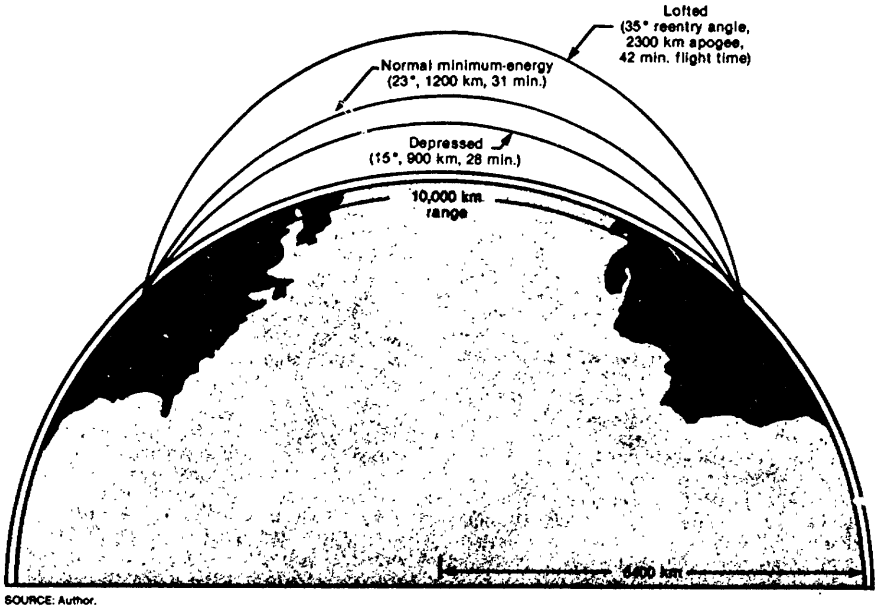
The most important trajectory variations from the point of view of boost phase intercept are variations in boost profile. Boosters like MX were designed with no regard for boost phase BMD, and optimizing their design gave rise to rather long boost times. But boost phase can be shortened—giving less time for boost phase weapons to act—and accomplished within the atmosphere—where certain directed-energy weapons cannot penetrate—with relatively little reduction in payload or increase in missile size. Fast burn is accomplished most easily with solid-fueled rockets. Liquid-fueled boosters like the Soviet SS-18s and SS-19s burn more slowly and burn out at higher altitudes. Thus while MX burns out at 200 km after 3 minutes of boost, the SS-18 burns out at 300-400 km after 5 minutes. The next generation of Soviet ICBMs will reportedly employ solid propellants.

Studies performed for the Defense Department[1] showed that with a 25 percent reduction in payload, a booster about the same size as MX could be built which would burn out in less than 1 minute at only 80 to 90 km, well within the sensible atmosphere. At 90 km the atmosphere is still too dense for extremely accurate RV deployment or for deployment of lightweight RV decoys and other penetration aids aimed at later defensive layers: these functions require an additional 10 to 15 seconds of precision deployment between 90 and 110 km. If the offense needs precision accuracy for some of its ICBMs but fears intercept during these additional few seconds of high-altitude operation, mounting one or two RVs on each of several "microbuses" instead of all the RVs on a single bus affords some protection. Each microbus would contain a simple guidance system only good enough to carry the RVs from upper stage burnout to 110 km. Instead of presenting one target above 90 km, therefore, such a booster would present several targets.

The United States is studying a "Midgetman" missile endorsed by the President's Commission on Strategic Forces (the Scowcroft Commission)

[1] "Short Burn Time ICBM Characteristic and Considerations," Martin Marietta Denver Aerospace, July 20, 1983 (UNCLASSIFIED)

Figure 2.2.—Normal (Minimum-Energy), Lofted, and Depressed ICBM Trajectories, Drawn to Scale



SOURCE: Author.

with weight 15 to 25 percent that of MX and carrying one warhead. Midgetman's warhead and bus are combined in one hardened structure. Table 2.1 shows the characteristics of Midgetman variants designed to face a boost-phase intercept system. The fast-burn version burns out at 80 km after 50 secs of boost. With a 10 percent increase in weight, the fast-burn version can carry a substantial payload of penetration aids. A low-flight-profile version is intended to stay within the atmosphere until burnout, protecting it from some types of directed-energy weapon. In the hardened version, one gram of ablative or other shielding material has been applied to each square centimeter of the entire booster body (if the boost-phase intercept system did not begin operation until a minute or so after launch, the first stage might not have to be hardened). These small boosters are all estimated to cost $10 to $15 million per copy, assuming a buy of 1,000 boosters. Costs for the second and subsequent thousand would of course be substantially smaller. These costs are two to three times higher per RV than MX.

The Soviet ICBM arsenal today comprises about 1,400 boosters, more than two-thirds of them MIRVd. Most are slow-burning liquid-fueled boosters. The U.S. arsenal contains about 1,000 faster-burning solid-fueled Minuteman boosters, about half of them MIRVd. Both sides are adding solid boosters to their arsenals in the 1980's.

The geographic distribution of offensive boosters can also be important to space-based boost-phase defenses. The number of satellites required in a defensive constellation usually increases if all opposing ICBM silos are concentrated in one region and decreases if the silos are spread over

Table 2.1.—ICBM Booster Characteristics

	Gross weight (kg)	Length (m)	Width (m)	Type	Booster burnout time (seconds after launch)	Booster burnout altitude (km)	End bussing time (seconds after launch)	End bussing altitude (km)	Comments
SS-18	220,000[a]	35.0	3.0	2-stage liquid	~300	~400	—	—	—
MX Peacekeeper	89,000	21.3	2.3	3-stage solid	180	200	650	1,100	Carries 10 RVs on a single bus
MIRVd fast-burn booster	87,000	22.9	2.1	2-stage solid	50	90	60	110	Deploys several "microbuses" carrying RVs and decoys
Midgetman	19,000	12.1	1.5	2-stage solid	220	340	—	—	Carries one accurate RV
Midgetman fast-burn	20,000	13.8	1.5	2-stage solid	50	80	—	—	Carries one accurate RV
Midgetman fast-burn with midcourse penetration aids	22,000	14.3	1.5	2-stage solid	50	80	—	—	Carries one accurate RV plus decoys
Midgetman with low flight profile	25,000	13.4	1.5	1st stage solid, 2nd liquid	220	100	—	—	Carries one accurate RV
Hardened Midgetman	30,000	15.1	1.5	1st stage solid, 2nd liquid	220	320	—	—	Carries one accurate RV; entire booster covered with 1gm/cm² shielding
Pershing II	7,500	10.5	1.0	2-stage solid	100	—	—	—	—

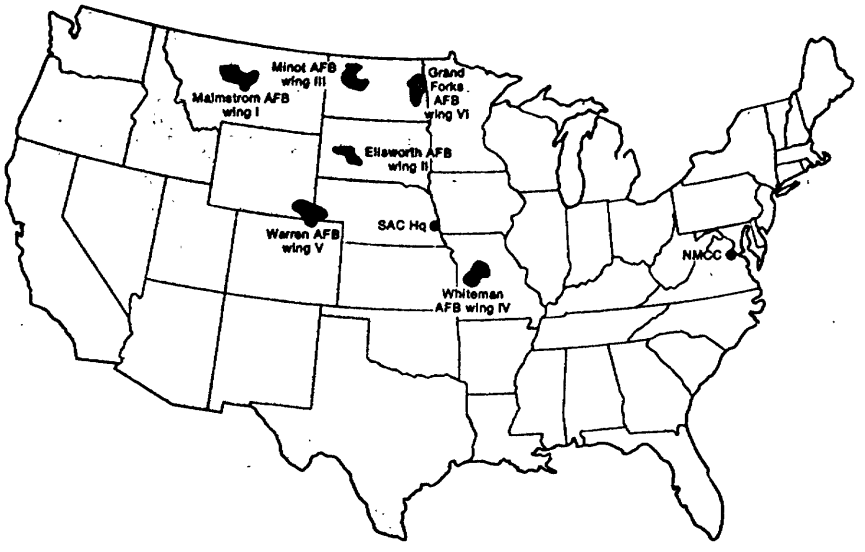
[a] *Soviet Space Programs 1976-1980* (Committee on Commerce, Science, and Transportation, U.S. Senate, December 1982), Part 1, p. 83

SOURCE: Except where indicated, "Short Burn Time ICBM Characteristics and Considerations," and accompanying backup, presented to DTST, July 20, 1983, by Martin Marietta Denver Aerospace (UNCLASSIFIED)

wide land areas. (On the other hand, too much concentration allows defensive satellites to be focused on one region by choosing the orbits judiciously.) Soviet SS-18 ICBMs, their largest MIRVd missiles, are organized into 6 wings of about 50 missiles each, spread out over a large region of the U.S.S.R. U.S. Minuteman missiles are organized into 6 wings of about 150 missiles each. Figures 2.3 and 2.4 show the geographic distributions.

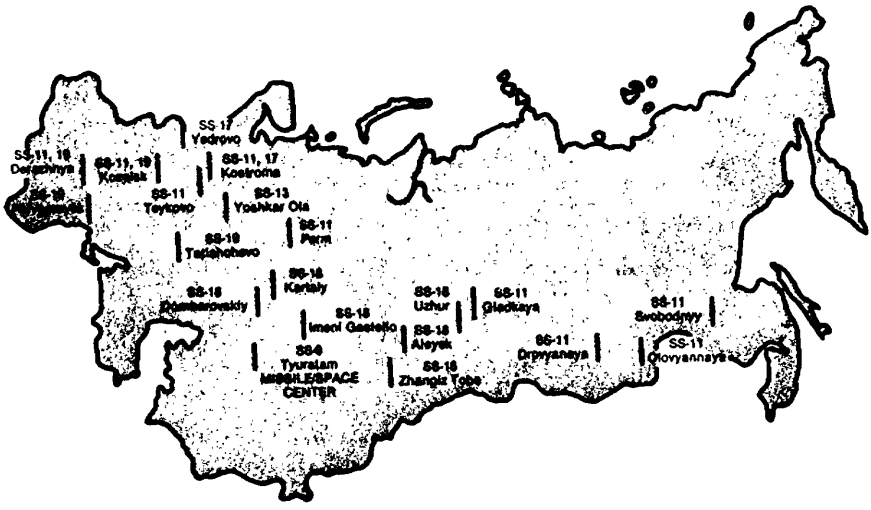
The capabilities of a hypothetical future U.S. BMD should be measured against the *future* and *potential* Soviet ICBM arsenal, not against today's arsenal. The future arsenal will differ due to the natural retirement of old ICBMs and introduction of new ones, and because the Soviets might well react with new and different deployments when they learn of any U.S. plans to deploy defenses. It is impossible to project Soviet deployments far into the future. A reasonable "baseline" estimate for the Soviet ICBM arsenal 15 to 20 years from now might assign them the same number of boosters they have today, but with burn characteristics similar to the U.S. solid-propellant MX. This Background Paper indicates where and how the effectiveness of a hypothetical U.S. defense depends on the nature of the offensive arsenal it faces. In addition to having shorter average burn times, future Soviet ICBMs could be more numerous, deployed less widely geographically, less highly MIRVd, hardened against intercept, and so on.

Figure 2.3.—Present U.S. ICBM Deployment Areas



SOURCE: OTA, *MX Missile Basing*, p. 274.

Figure 2.4.—Present U.S.S.R. ICBM Deployment Areas



Type	ICBMs Number
SS-11	550
SS-13	60
SS-17	150
SS-18	308
SS-19	330
	Total 1398

SOURCE: U.S. DOD, *Soviet Military Power*, 2nd ed., p. 14

Section 3
DIRECTED ENERGY WEAPONS FOR BOOST-PHASE INTERCEPT

This section describes the entire set of "beam weapons" being considered in the United States today for boost-phase ICBM intercept. Though these weapons receive the most attention, the "kill mechanism" that destroys the booster is not necessarily the most important or technically challenging part of an overall defense system. The next section describes other essential elements of a boost-phase defense.

A revisit to this subject several years from now might well find a new family of directed energy concepts receiving attention. But for now the devices described in this section are the basis for assessments of the prospects for efficient boost-phase defense, in the Defense Department and elsewhere (fig. 3.1). Though some of these concepts are new, many have in fact existed in one form or another for more than twenty years.

Figure 3.1

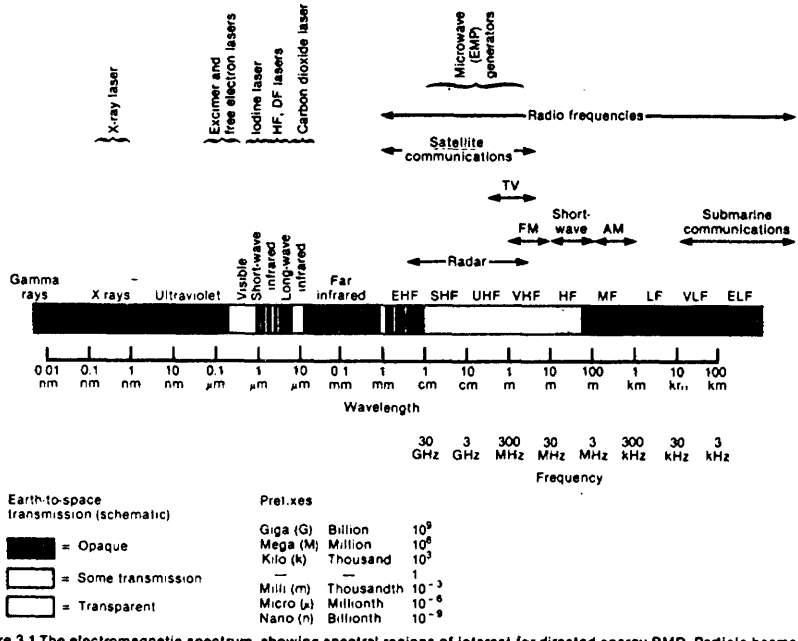


Figure 3.1 The electromagnetic spectrum, showing spectral regions of interest for directed energy BMD. Particle beams and kinetic energy weapons are not shown because their energy does not consist of electromagnetic radiation, but of atomic and macroscopic matter, respectively. Source: Author

For each concept this section attempts to work through, with some concreteness, the design of a hypothetical defensive system based on the concept. The resulting designs are *illustrative only;* no significance should be attached to precise numbers. Precision is simply not possible in the current state of technology and study of these concepts.

In all cases, the "current state of technology" (however this is defined in each case) is far from meeting the needs of truly efficient boost-phase intercept. The systems designed in this section illustrate the level to which technology would have to progress to be "in the ballpark." Much attention fastens on the gulf between the current state of technology and the ballpark requirements. This section does not emphasize such comparisons for several reasons. First, in some cases details of the precise status of U.S. research is classified. Second, and more importantly, quantitative comparisons (e.g., "A millionfold increase in brightness is required to fashion a weapon from today's laboratory device") can mislead unless accompanied by a deeper explanation of the technology; and the same quantitative measures are not appropriate for all technologies. Third, and most importantly, such comparisons imply that learning how to build the right device is tantamount to developing an efficient missile defense, which is far from true: equally crucial are design of a sensible system architecture, cost, survivability, resilience to countermeasures, and the myriad detailed limitations that do not turn up until later in development.

3.1 SPACE-BASED CHEMICAL LASERS: A FIRST EXAMPLE

This concept of directed energy weapon has been the one most frequently discussed in recent years for boost-phase ICBM intercept. For this reason (and not necessarily because it is the most plausible of all the concepts), it will be used to introduce certain features common to all the schemes that follow.

Making and Directing Laser Beams

A molecule stores energy in vibrations of its constituent atoms with respect to one another, in rotation of the molecule, and in the motions of the atomic electrons. The molecule sheds energy in the form of emitted light when it makes transitions from a higher-energy state to a lower-energy state. Lasing takes place when many molecules are in an upper state and few are in a lower state: one downward transition then stimulates others, which in turn stimulate yet more, and a cascade begins. The result is a powerful beam of light.

Energy must be supplied to the molecules to raise most of them to the upper state. This process is called pumping. In the case of the chemical lasers considered in this section, the pumping energy comes from the chemical reaction that makes the lasant molecules: hydrogen and fluorine react to form hydrogen fluoride (HF) molecules in an upper state. The other requirement for lasing—few molecules in the lower state—is satisfied simply by removing the molecules from the reaction chamber after they have made their transitions to the lower state and replacing them with freshly made upper state molecules. The pumping process is not perfect: not all the pumping energy ends up as laser light. The ratio of pumping energy in to laser energy out is called the efficiency of the laser.

Laser light is special in two respects: its frequency is precise, since all the light comes from the same transition in all the molecules; and the light waves from all the molecules emerge with crests and troughs aligned, since the waves are produced cooperatively. These special features make it possible to focus the laser energy with mirrors into narrow beams characterized by small divergence angles (see fig. 3.2). Nonetheless, there is a limit to the divergence angle that even a perfect laser with perfect mirrors can produce. The divergence angle (in radians) can be no smaller than about 1.2 times the wavelength of the light divided by the diameter of the mirror. Thus a laser with 1 micrometer (=1 micron)

Figure 3.2

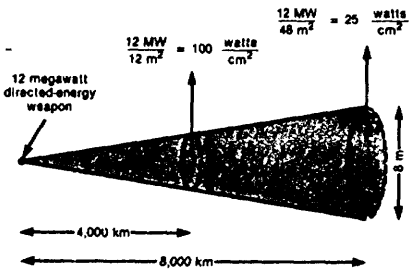


Figure 3.2 Basic power relationships for directed energy weapons. If the directed energy weapon has a divergence angle of 1 microradian, the spot size at a range of 4000 kilometers is 4 meters (12 feet). In this figure, the divergence angle is exaggerated about 1 million times. (For comparison of scale, the Earth's radius is about 6,400 km.) If the directed energy weapon emits 12 megawatts of power, a target within the spot at 4,000 km receives 100 watts on each square centimeter of its surface. (For comparison, 100 watts is the power of a lightbulb, and a typical commercial powerplant produces 1,000 megawatts). Since a watt of power equals one joule of energy per second this weapon would take 10 seconds to apply a kilojoule per square centimeter (1 KJ/cm²) to the target at 4,000 km range. Source: Author

wavelength projected with a 1 meter mirror could have at best a 1.2 microradian divergence angle, making a spot 1.2 meters wide at a range of 1,000 kilometers (refer to fig. 3.2).[1] This perfect performance is called the diffraction limit. Dividing the laser power output by the size of the cone into which it is directed (cone size is measured in units called steradians; a divergence angle of x radians results in a cone of size $\pi x^2/4$ steradians) yields the laser's "brightness," the basic measure of a weapon's lethality.

Destroying Boosters with Lasers

Assuming a high-energy laser with small divergence angle can be formed, stabilized so it does not wave about (jitter), and aimed accurately, what effect will it have on an ICBM booster? No clear answer to this question can be given without more study and testing. Estimates of the hardness achievable with future boosters are probably reliable within a factor of two or three, though estimates of the hardness of current Soviet boosters are probably reliable only to a factor of 10 or so.

Roughly speaking, laser light can damage boosters in two distinct ways. With moderate intensities and relatively long dwell times, the laser simply burns through the missile skin. This first mechanism is the relevant one for the chemical lasers described in this section. The second mechanism requires very high intensities but perhaps only one short pulse: the high intensity causes an explosion on and near the missile skin, and the shock from the explosion injures the booster. This mechanism, called impulse kill, is more complex than thermal kill and is less well understood. It will be discussed in the next section.

Bearing in mind the uncertainties in these estimates, especially the complex interaction of heating with the mechanical strains of boost, the following estimates are probably reliable: A solid-fueled booster can probably absorb without disruption up to about 10 kilojoules per square centimeter (kJ/cm²) on its skin if a modicum of care is taken in the booster's design to eliminate "Achilles' heels." This energy fluence would result from 1 second of illumination at 10 kilowatts per square centimeter (kw/cm²), since one watt equals one joule per second.[2] Applying ablative (heatshield) material to the skin can probably double or triple the lethal fluence required. Applying a mirrored reflective coating to the booster is probably not a good idea, since abrasion during boost could cause it to lose its lustre. Spinning the booster triples its hardness, since a given spot on the side of the booster is then only illuminated about a third of the time.[3] On the other

[1] The spot from a perfect laser with perfect mirrors would actually be brighter at the center than at the edges. The full angle subtended by this spot (the Airy disk from null to null in the diffraction pattern), is 2.4 times the wavelength divided by the mirror diameter, but most of the energy is in the central fourth of this area: hence the use in the text of the multiplier 1.2.

[2] The lethal fluence (in kJ/cm²) must accumulate over a relatively short time, so that the booster wall suffers a high rate of heating. Thus a flux of 30 watts/cm² would deposit 10 kJ/cm² in 330 sec of dwell time, but such a slow rate of heating would probably not damage the booster.

[3] It is possible that uniform heating around the circumference of the booster introduces lethal mechanisms distinct from those that apply to heating a single spot on the side of the booster. In that case, spinning the booster might not lengthen the required dwell time by the full amount dictated by geometry.

hand, currently deployed boosters, especially the large liquid Soviet SS-18s and SS-19s, might be vulnerable to 1 kJ/cm² or even less. These too could be hardened by applying heatshield material.

An Orbiting Chemical Laser Defense System

Consider a space-based BMD system comprised of 20-megawatt HF chemical lasers with 10 meter mirrors. The HF laser wavelength of 2.7 microns is attenuated as it propagates down into the atmosphere, but most of the light gets down to 10 km or so altitude. Deeper penetration is not really needed, since the laser would probably not be ready to attack ICBMs until after they had climbed to this altitude, and in any event clouds could obscure the booster below about 10 km. (Substituting the heavier and more expensive deuterium, an isotope of hydrogen, to make a DF laser at 3.8 micron wavelength would alleviate attenuation, but the longer wavelength would require larger mirrors.)

A perfect 10 meter mirror with a perfect HF laser beam yields 0.32 microradian divergence angle. The spot from the laser would be 1.3 meters (4.0 ft) in diameter at 4 megameters (4,000 kilometers) range. 20 megawatts distributed evenly over this spot would be an energy flux of 1.5 kw/cm². The spot would need to dwell on the target for 6.6 seconds to deposit the nominal lethal fluence of 10 kJ/cm². At 2 megameters (Mm) range, booster destruction would require only a fourth of this time, or 1.7 seconds of illumination. Since light takes about a hundredth of a second to travel 4 megameters and the booster is traveling a few kilometers per second, the booster moves about 50 meters in the time it takes the laser light to reach it. The laser beam must therefore lead the target by this distance.

The next step is to choose orbits for the satellites so that the U.S.S.R.'s ICBM silos are covered at all times and so that there are enough satellites overhead to handle all 1,400 of the present Soviet booster population. Equatorial orbits (fig. 3.3) give no coverage of the northern latitudes where Soviet ICBMs are deployed. Polar orbits give good coverage of northern latitudes but concentrate satellites wastefully at the poles where there are no ICBMs. The optimum constellation consists

Figure 3.3

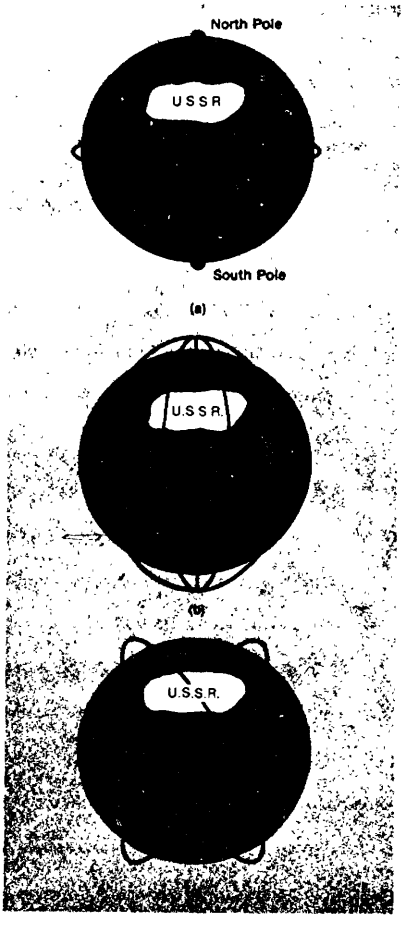


Figure 3.3 Designing a constellation of directed energy weapon satellites for optimum coverage of Soviet ICBM fields. Equatorial orbits (a) give no coverage of northern latitudes. Polar orbits (b) concentrate coverage at the north pole. Inclined orbits (c) are more economical. Slight additional economies are possible in some cases with further elaboration of the constellation design. Source: Author

of a number of orbital planes inclined about 70° to the equator, each containing several satellites.

The shorter the lethal range of the directed energy weapon, the lower and more numerous the satellites must be. For instance, with a lethal range of 3 Mm, 5 planes containing 8 satellites each, or a total of 40 satellites, are needed to ensure that Soviet boosters exiting Soviet airspace would be within lethal range of one satellite. If the lethal range is increased to 6 Mm, only 3 planes of 5 satellites each are needed. This dependence of constellation size on weapon range is displayed in figure 3.4. (It is possible to adjust these numbers a bit by using slightly elliptical orbits with apogees over the northern hemisphere, adjusting inclinations and phasing, etc.). In the present example, requiring that at least one HF laser be no further than 4 Mm from each Soviet ICBM site at all times (corresponding to no longer than 6.6 seconds dwell time per booster) results in the illustrative constellation of 32 orbital positions shown in figure 3.5.

Since the 1,400 Soviet boosters currently deployed are spread out over most of the Soviet Union, perhaps 3 of the 32 orbital positions would be over or near the Soviet Union at a time, able to make efficient intercepts. That is, only one in 11 deployed U.S. battle stations would participate in a defensive engagement. The ratio of the total number of battle stations on orbit to the number in position to participate in a defensive engagement is called the absentee ratio. The inevitable waste reflected in the absentee ratio—

Figure 3.4

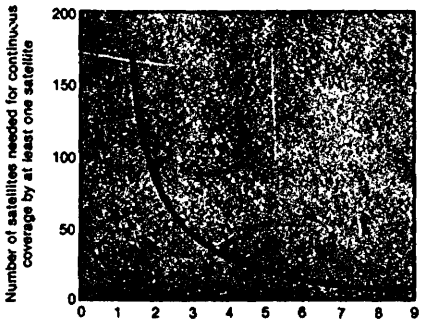
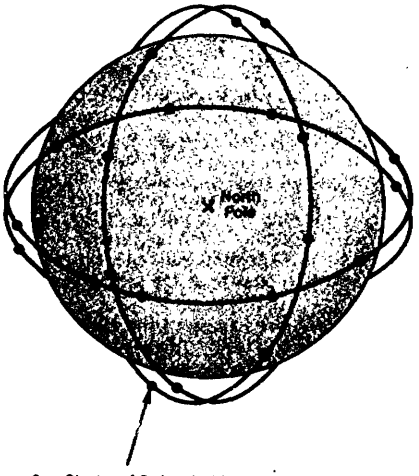


Figure 3.4 The number of satellites needed in a constellation to ensure that at least one satellite is over each Soviet ICBM field at all times depends on the effective range of the directed energy weapon. For every one defensive weapon required overhead a Soviet ICBM field to defend against a rapid Soviet attack, an entire constellation must be maintained on orbit. Since there are many Soviet ICBM fields distributed over much of the Soviet landmass, more than one satellite in each constellation would be in position to participate in a defensive engagement. The ratio of the number of satellites in the constellation to the number over or within range of Soviet ICBM fields is called the absentee ratio. If all Soviet ICBMs were deployed in one relatively small region of the U.S.S.R., the absentee ratio would be the same as the number of satellites in the constellation. Source: Author

Figure 3.5



0 = Cluster of 5 chemical laser battle stations
Total of 32 x 5 = 160 battle stations

Figure 3.5 Constellation of hypothetical directed energy weapon satellites with 4,000 km range. The orbits are circular with 1000 km altitude. Each of the four orbital planes consists of eight positions spaced 45° apart around the circle. In the example given in the text, five chemical laser battle stations are clustered at each point shown in this figure, for a total of 32 x 5 = 160 battle stations. Source: Author

usually on the order of 10—offsets an oft-cited theoretical advantage of boost-phase intercept, namely, that intercepting one booster saves buying 10 interceptors for the booster's 10 RVs. On the other hand, coverage of the U.S.S.R.'s ICBM fields automatically gives good coverage of essentially all submarine deployment areas. Obviously the absentee ratio would be 32—the full constellation size—and not 32/3 = 10.7 if Soviet ICBM silos were not spread out so widely over Soviet territory but were deployed over a third or less of the Soviet landmass, so that only one of the 32 U.S. satellites was within range.

Three of the earlier described laser satellites in position over the Soviet ICBM fields are not enough to intercept 1,400 boosters if all or most of the boosters are launched simultaneously. Each satellite can only handle a few boosters because it must dwell for a time on each one. The time a chemical laser must devote to each booster depends on the satellite's position at the moment of attack—6.6 seconds for 4 Mm range, 1.7 seconds for 2 Mm range, etc. Taking 2 Mm as an average range for the 32-satellite constellation (hoping the Soviets do not choose a moment when most of the U.S. satellites are farther t[illegible] 2 Mm from the ICBM flyout corridors to launc[illegible] all their boosters simultaneously), a laser must devote an average of 1.7 seconds to each booster.

If the boosters in the future Soviet arsenal resemble the U.S. MX, and the defense waits 30 seconds or so to confirm warning and to wait for the boosters to climb to an altitude where the HF laser can reach, each booster is accessible for 150 seconds of its 180 second burn time. Each laser can therefore handle no more than 90 boosters, even with instant slewing of the beam from target to target. If 1,400 Soviet boosters were launched simultaneously, (1,400)/(90) ≅ 15 lasers would be needed in position, for a worldwide total (multiplying by the absentee ratio) of (10.7) × (15) = 160 satellites.

If the Soviets doubled their arsenal to 2,800 boosters, the United States would need to deploy another 160 satellites, possibly an uncomfortable cost trade for the United States.

What is worse, if the Soviets deployed 1,400 missiles in a *single region* of the U.S.S.R. (at a U.S.-estimated cost of $21 billion for Midgetman-like ICBMs; see section 2 above), the US would have to build, launch, and maintain on orbit an additional (32)×(1400)/(90) ≅ 500 lasers plus their fuel and support equipment.

If Soviet boosters were covered with shielding material and spun during flight to achieve an effective hardness of, say, 60 kJ/cm², a laser would have to devote 10 seconds to each booster at 2 Mm range, requiring a sixfold increase in the number of satellites, to 960. Alternatively, the average range of each engagement could be reduced to keep the dwell time at 1.7 seconds, with corresponding increase in constellation density (fig. 3.4). Either way, the number of U.S. satellites would grow to nearly the number of Soviet boosters intercepted.

Table 3.1.—Variation of the Number of Chemical Laser Battle Stations Needed to Handle a Simultaneous Launch of Soviet ICBMs, Depending on Characteristics of the Soviet Arsenal and the U.S. Laser Defense

Departure from baseline	Number of Soviet boosters	Booster characteristics	Geographic distribution	Hardness (kJ/cm²)	Laser power (MW) and aperture diameter (m)	Approximate number of battle stations needed
Baseline	1,400	MX-like	Current Soviet	10	20/10	160
Booster number	2,800	MX-like	Current Soviet	10	20/10	320
Deployment geography	1,400	MX-like	One region	10	20/10	500
Booster hardness	1,400	MX-like	Current Soviet	60	20/10	960
Laser brightness	1,400	MX-like	Current Soviet	10	80/50 (100 times brighter)	20-30
Booster burn time	1,400	Fast-burn	Current Soviet	10	20/10	800-1,600
Booster burn time	1,400	SS-18-like	Current Soviet	10	20/10	90

SOURCE: Author.

If the United States developed a battle station 100 times brighter (using, say, a 80 MW laser with an effective mirror diameter of 50 meters), a few lasers overhead (20 to 30 total worldwide) could easily handle an attack of 1400 boosters hardened to 10 kJ/cm². If the boosters were hardened to 60 kJ/cm², over 100 such lasers would be needed.

Deployment by the Soviets of 1400 fast-burn boosters would give the U.S. lasers just 20 to 40 seconds, rather than 200 seconds, to destroy all the boosters. The U.S. constellation would consequently need to grow by a factor 5 to 10, to 800 to 1600 satellites!

Table 3.1 summarizes how the size of the defensive deployment varies with the parameters assumed.

Requirements for a Chemical Laser Defense

Figure 3.6 displays the performance of various hypothetical HF lasers. Keeping the size of the battle station constellation down to a hundred rather than several hundred satellites means lethal ranges of at least 4 Mm with illumination times less than about 1 second, assuming the defense must be capable of intercepting 1,000 to 2,000 Soviet boosters with launches timed to keep the boosters as far from the U.S. lasers as possible. Further assuming Soviet booster hardening to at least 10 kJ/cm² results in a requirement for chemical lasers considerably brighter than the 20 MW, 10-meter laser described above. A hundredfold increase in brightness would be achieved by a laser with power 80 MW and effective mirror diameter 50 meters.

Such a laser would be about 10 million times brighter than the carbon dioxide laser on the Air Force's Airborne Laser Laboratory. The current Alpha laser program of the Defense Advanced Research Projects Agency (DARPA) aims at a construction of an HF laser of just a few megawatts and built only for ground operation. Nonetheless, there is no fundamental technical reason why extremely bright chemical lasers cannot be built. In theory, several lasers can be operated together so that the brightness of the resulting beam increases with the square of the number

Figure 3.6

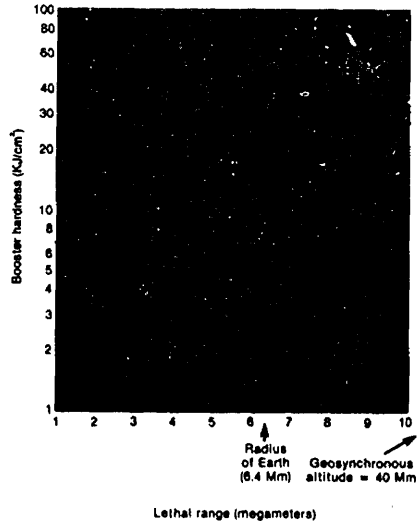


Figure 3.6 Lethal range versus booster hardness for HF chemical lasers of various sizes and dwell times. The labels on the curves have the format (laser power in megawatts, mirror diameter in meters) followed by the amount of time the laser devotes to destroying each booster. Source: Author

of lasers: 10 lasers combined in this way would produce a beam 100 times brighter than each individual laser. The trick is to arrange for the troughs and crests of the light waves from all the lasers to coincide. This theoretical prospect is unlikely to be realized with HF lasers, since their light is actually emitted at several wavelengths and with shifting patterns of crests and troughs.

To yield diffraction-limited divergence, the mirror surface must be machined to within a fraction of a wavelength of its ideal design shape over its entire surface. Since the mirror is over a million wavelengths across, avoiding small figure errors is a severe requirement. A number of small mirrors can obviously combine to produce one large optical surface if their positions are all aligned to within a fraction of a wavelength. The

mirrors must maintain perfect surface shape in the face of heating from the laser beam, vibration from the chemical reaction powering the laser, and vibrations set up in the mirror as it is slewed. Substantial hardening of mirrors to radiation from nuclear bursts in space and to the x-ray laser (described below) would be a challenging task. The 2.5-meter diameter mirror on NASA's Space Telescope was produced without these constraints.

An extremely optimistic outcome of HF laser technology—near the theoretical limit for converting the energy of the chemical reactants to laser energy—would require more than a kilogram of chemicals on board the satellite for every megajoule radiated. A spot diameter of 2 meters at the target and a lethal fluence of 10 kJ/cm² over this area results in an energy expenditure of 300 MJ per booster. Destroying 1,000 Soviet boosters therefore requires, reckoning very crudely, 300,000 kg of chemicals in position over the Soviet ICBM field, or perhaps 10 million kg on orbit worldwide. The space shuttle can carry a payload of about 15,000 kg to the orbits where the satellite battle stations would be deployed. About 670 shuttle loads would therefore be needed for chemicals, with perhaps another half as many for the spacecraft structures, the lasers and mirrors, construction and deployment equipment, and sensors. 1,000 shuttle missions for every 1,000 Soviet boosters (perhaps Midgetmen) deployed in reaction to the U.S. defense is an impractical competition for the United States. Use of HF chemical lasers for BMD therefore requires remarkably cheap heavy-lift space launch capability in the United States.

The remaining components of the chemical laser defense system—sensors, aiming and pointing technology, and communications— are for the most part generic to all directed energy weapons and are discussed in section 4. Section 5 presents countermeasures the Soviets might take to offset or nullify a chemical laser defense.

3.2 GROUND-BASED LASERS WITH SPACE-BASED MIRRORS

A slight variant of the previous concept puts the laser on the ground and mirrors in space, reflecting the light back down toward Earth to attack ascending boosters. This scheme avoids placing the laser and its power supply in space, though mirrors, aiming equipment, and sensors remain. The excimer and free-electron lasers considered for this scheme are in fact likely to be rather cumbersome, so ground basing them might be the only practical way to use them for BMD. The lasers would emit at visible or ultraviolet wavelengths about ten times shorter than the near-infrared wavelengths of the HF and DF chemical lasers in the space-based concept. Shorter wavelengths permit use of smaller (though more finely machined) mirrors. The high power available with ground basing suggests at least the possibility of impulse rather than thermal kill of boosters.

The term excimer is a contraction of "excited dimer." A dimer is a molecule consisting of two atoms. The dimers considered for these lasers contain an atom of noble gas and a halogen atom, making dimers like xenon fluoride (XeF), xenon chloride (XeCl), and krypton fluoride (KrF). The laser light comes from dimers in an excited upper state decaying to a lower state, just like in the HF laser. Excimer lasers tend to emit light in pulses rather than in a continuous wave. The population of upper-state molecules is provided by pumping with electric discharges in a rather complicated process. The population of lower-state molecules remains small because the lower-state dimer is unstable and quickly breaks up into its two constituent atoms. The pumping process for excimer lasers is inefficient, so only a small fraction of the energy put into the laser in the electric discharge emerges as laser light. Powerful excimer lasers would therefore be large and would need to vent large amounts of wasted energy; these characteristics make them unsuitable for space basing. Development of excimer lasers is at an early stage, and no excimer lasers exist with anything remotely approaching the characteristics needed for this boost phase intercept concept.

Figure 3.7

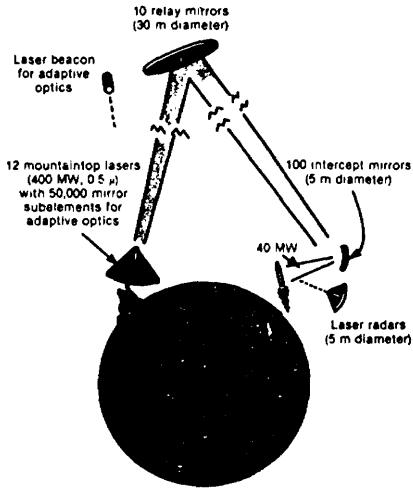


Figure 3.7 Illustrative configuration of ground-based excimer or free-electron laser and space-based mirrors for thermal kill of Soviet ICBM boosters. Source: Author

Power outputs achieved in the laboratory are still several orders of magnitude less than the average power needed for thermal kill, and the energy achieved in a single pulse is much smaller than the single-pulse energies needed for impulse kill.

The working of a free-electron laser (FEL) is more complicated.[4] As the name suggests, the light-emitter (lasant) is free electrons emitted from a particle accelerator. Pumping therefore originates in the electrical source powering the accelerator. The free electrons from the accelerator are directed into a tube called the wiggler that has magnets positioned along its length. The magnets cause the electrons to wiggle back and forth as they transit the tube. As they wiggle, the electrons emit some of their energy as light. The presence of light from one electron causes others to emit in the usual cooperative manner of a laser, and a cascade begins. By adjusting the positions of the magnets and the energy of the electrons, the wavelength of the light can be tuned to any value desired. The only advantage of the FEL over excimer lasers is the high efficiency that can (theoretically) be obtained with the former. It has been suggested that it might even be possible to position FELs in space like HF chemical lasers. FEL operation at visible wavelengths is in its infancy, and the experimental devices used are many millions of times less powerful than those required in this BMD.

The BMD scheme calls for a large ground based excimer or free electron laser, relay mirrors at high altitude to carry the laser beam around the curve of the Earth, and intercept mirrors to focus the beams on individual boosters (fig. 3.7). The characteristics of a nominal system for thermal booster kill are easily ascertained. Suppose first that there are enough intercept mirrors so that the average range from mirror to booster is 4 Mm, and suppose the Soviet boosters are destroyed with 10 kJ/cm² deposited on a spot as small as several centimeters wide. Assume the excimer or free electron laser operates at about 0.5 microns, in the visible band. Then a 5 m intercept mirror will produce a spot 50 cm wide at 4 Mm range. If a half second of the main laser beam is devoted to each booster, then the required 10 kJ/cm² will be accumulated if the power reflected from each intercept mirror is 40 MW.

Only about a tenth of the power emitted by the ground based laser in the United States would be focused on the booster over the U.S.S.R. The remainder would be lost in transit through the atmosphere and in reflection from the two mirrors. Thus a 400 MW laser is required.

Passage through the atmosphere poses a number of problems for the primary laser beam. The most important source of interference is turbulence in the air, causing different parts of the laser beam to pass through different optical environments when exiting the atmosphere. Each part of the beam suffers a slightly different disruption, and the beam that emerges does not have the

[4]See Charles A. Brau, "Free Electron Laser: A Review," *Laser Focus*, March 1981; *Physics Today*, December 1983, p.17.

orderly arrangement of crests and troughs needed for diffraction-limited focusing from the intercept mirror. Without compensation for atmospheric turbulence, the ground-based laser scheme is completely impractical. Fortunately, the pattern of turbulence within the laser beam, though constantly changing, remains the same for periods of a few milliseconds. Since it takes only 0.1 millisecond for light to make a round trip through the atmosphere, the effect of turbulence on the laser beam can be compensated for with the following technique, called adaptive optics: A low-power laser beacon is positioned near the relay mirror. A sensor on the ground observes the distortion of the beacon beam as it passes through the atmosphere. The beam from the ground-based laser is then predistorted in just such a way that its passage through the same column of air transited by the beacon beam re-forms it into an undistorted beam.

Figure 3.7 shows the many components required by the ground-based laser concept. Since each Soviet booster requires 0.5 sec of beam at some time during its 200 sec. boost phase, four beams would be needed to handle 1,400 Soviet boosters launched simultaneously (assuming no retargeting delays). The lasers should be deployed on mountain tops to make atmospheric effects manageable, and enough should be deployed that at least four sites are always clear of cloud cover. The mirror on the ground would need to be tens of meters across and divided into tens of thousands of individually adjustable segments for predistortion of the wavefront. Each relay mirror would need to be accompanied by a beacon. Four large interception mirrors would be needed within 4 Mm of each Soviet ICBM flyout corridor, giving a worldwide constellation of a hundred or so.

The small laser wavelength means that all mirrors must be more finely machined than the mirrors for the chemical laser and can tolerate smaller vibrations and stresses due to heating from the laser beam. The small wavelength also results in a spot 10 times smaller at the target than the spot from a chemical laser beam at the same range. This small spot requires pointing accuracy ten times finer. Perhaps most important of all, the plume from the booster motor is too large to serve as target for such a narrow beam. Some way of seeing the actual missile body against the background of the plume is needed for the short-wavelength laser schemes (and for some configurations of chemical lasers). One answer to this problem, described in section 4 below, is to position near each intercept mirror a low-power laser and a telescope (a laser radar or ladar): the laser illuminates the booster and the telescope observes the reflected laser light, directing the pointing of the intercept mirror. The ladar telescope must have a mirror as large as the intercept mirror, since it must be able to "see" a spot as small as that made by the beam.

A single immense laser pulse that deposits 10 kJ/cm² in a very short time—millionths of a second rather than a second— might cause impulse kill rather than thermal kill. In impulse kill, the laser pulse vaporizes a small layer of the booster skin and surrounding air. The superheated gases then expand explosively, sending an impulsive shockwave into the booster. A strong enough shockwave might cause the booster skin to tear. The advantage of this kill mechanism is that it would be very difficult to protect boosters from it. The disadvantages are that impulse kill requires prodigious laser pulses and mirrors that can withstand them, and that the mechanism is poorly understood and depends on myriad factors like the altitude of the booster at the moment it is attacked.

3.3 NUCLEAR BOMB-PUMPED X-RAY LASERS: ORBITAL AND POP-UP SYSTEMS

The U.S. Government has revealed efforts at its weapon laboratories to use the energy of a nuclear weapon to power a directed beam of x-rays. Such devices are said to constitute a "third generation" of nuclear weapons, the first two generations being the atomic (fission) and hydrogen

(fusion) bombs. Each succeeding generation represented a thousandfold increase in destructive energy, from a ton of high explosive to a kiloton fission weapon to a megaton fusion weapon. The third generation weapon uses the same amount of energy as the fusion weapon, but directs much of that energy toward the target rather than allowing it to escape in all directions. At the target, therefore, the energy received is much greater than the energy that would be received from a hydrogen bomb at the same range.

X rays lie just beyond ultraviolet light on the electromagnetic spectrum and have wavelengths about a thousand times smaller than visible light (see fig. 3.1). Compared to the infrared, visible, and ultraviolet lasers in the previous sections, the x-ray laser produces much more energy from its bomb pump, but the energy is spread out over a larger cone. The lethal ranges for boosters turn out to be roughly comparable for all these types of directed-energy device. Obviously the x-ray laser delivers all its energy in one pulse, so there is no question of dwell time on the target. Very short-wavelength x-rays penetrate some distance into matter (witness dental and medical x-rays), but the longer-wavelength x-rays produced by a laser device do not penetrate very far into matter or into the atmosphere.

Orbiting and ground-based "pop-up" systems have been proposed as ways to make use of the x-ray laser for boost phase BMD. Both of these schemes have attractive features but also serious drawbacks. It could well be that the x-ray laser device, if a powerful one can eventually be built, will be more useful in other strategic roles than boost-phase BMD.

X-Ray Lasers

Little has been revealed about the characteristics of the bomb-pumped x-ray laser being studied by the United States (the so-called Excalibur device), but some general information can be deduced from the laws of physics and, to a lesser extent, from the scientific literature here and in the Soviet Union.[5]

[5]F. V. Bunkin, V. I. Derzhiev, and S. I. Yakovlenko, *Soviet Journal of Quantum Electronics 11* (8), August 1981, p. 981. R. C. Elton, R. H. Dixon, and J. F. Seely, *Physics of Quantum Electronics 6* (1978), p. 243. Michael A. Duguay, *Ibid.*, p. 557. G. Chapline and L. Wood, *Physics Today*, June 1975, p. 40.

Figure 3.8

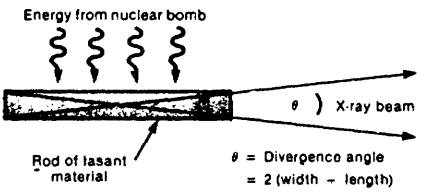


Figure 3.8 In an x-ray laser, a rod of lasant material is pumped to upper energy states by a nuclear bomb. Those cascades of downward transitions that travel lengthwise build up more energy than sideways-going cascades. As a result, most of the energy emerges from the ends of the rod into a cone with divergence angle equal to twice the rod width divided by its length. Source: Author

The pumping source for the x-ray laser is a nuclear bomb. The radiant heat of the bomb raises electrons to upper energy levels in atoms of lasant material positioned near the detonation (the chemical nature of the lasant material has not been revealed). As the electrons fall back again to lower levels, it can happen that for a moment many atoms are in a given upper level and few in a lower level; this is the necessary condition for lasing from the upper level to the lower level. The wavelength of the emitted x-ray is determined by the energy levels involved. The wavelength of the laser under study in the United States is classified. We will use a round number of 1 nm.

Since x-rays are not back-reflected by any kind of mirror, there is no way to direct the x-rays into a beam with optics like the visible and infrared lasers. Nonetheless, some direction can be given to the laser energy by forming the lasant material into a long rod. Recall that a laser beam builds up when light from one lasant atom stimulates the upper-to-lower-level transition in another atom, which stimulates a third, and so on. The result is a cascade of light heading in same direction as the light from the original atom. The light pulse gets stronger and stronger as it traverses the lasant medium stimulating more and more transitions. In a long rod of lasant material, cascades that get started heading lengthwise down the rod are highly amplified by the time they leave the rod, whereas sideways-going cascades remain small. The result is that most of the laser energy

emerges as a beam aligned along the rod axis (fig. 3.8).

The projected capabilities of the x-ray lasers being studied in the U.S. are classified; but it is fairly easy to determine the upper limit to how powerful such a laser could possibly be. Whether R&D will succeed in making such a perfect laser cannot be said. But it will become clear that something very close to the perfect laser is required for boost phase intercept, though a less successful development would still yield a potent antisatellite weapon.

A 1-megaton nuclear weapon releases about 4 billion megajoules of energy. By surrounding the bomb with lasant rods, most of this energy can be harnessed to pump the laser. Since the pumping mechanism for the x-ray laser is rather disorganized and wasteful, like the pumping mechanism for excimer lasers, at most a few percent of the bomb energy can be expected to end up in the laser beam.

The resulting 100 million megajoules or less of laser energy emerges from the rods into cones with relatively large divergence angle. It is easy to see why this divergence angle is much larger than the divergence angle obtained with the mirror-directed lasers treated in the previous section. The divergence angle is determined by the ratio of the width of the rod to its length, as in figure 3.8. A practical length for a rod is no more than about 5 meters. Making the rod thinner decreases the divergence angle, but beyond a certain point no further narrowing of the beam cone is possible. The limit arises from diffraction, just as with the infrared and visible lasers: the divergence angle of light emitted from an aperture (mirror, rod tip, or anywhere else) cannot be less than about 1.2 times the wavelength of the light divided by the diameter of the aperture. A very narrow rod therefore actually aggravates diffraction and produces a wide cone. Making the rod thinner results in no further narrowing of the beam when (1.2) (wavelength)/(rod width) ≅ (2) (rod width)/(rod length). For an x-ray wavelength of 1 nm and a rod length of 5 meters, this equation yields an optimum rod width of 0.06 mm and a minimum achievable (diffraction-limited) divergence angle of 20 microradians.

A 1-megaton bomb-pumped x-ray laser can therefore deposit no more than about 100 million megajoules into a cone no narrower than about 20 microradians. The x-ray pulse from detonating such a perfect laser would deposit about 300 kJ/cm² over a spot 200 meters wide at 10 Mm range.

Interaction of X-rays with Matter

X-rays of 1 nm wavelength do not penetrate very far into matter: all the energy from such a laser would be absorbed in the first fraction of a millimeter of the aluminum skin of a missile. This paper-thin layer would explode, sending a shockwave through the missile. Thus the x-ray laser works by impluse kill.

Another consequence of the opacity of matter to x-rays is that the laser beam would not propagate very far into the atmosphere. The altitude to which the beam would penetrate depends on the precise wavelength, which is classified. For the nominal 1 nm wavelength described above, boosters below about 100 km would be quite safe from attack. If the wavelength were much shorter, the x-rays would penetrate lower, reaching perhaps 60 km altitude or so. In what follows, it will be assumed that boosters are safe from x-ray laser attack below about 80 km.

One last consequence of the physics of x-ray interaction with matter is noteworthy. When an atom of matter absorbs an x-ray, it emits an electron. As x-rays are absorbed, it becomes harder and harder to remove successive electrons. Finally further x-rays cannot remove further electrons, and the matter becomes transparent. This phenomenon, called bleaching, means that a strong x-ray laser beam can force its way through a column of air by bleaching the column, but a weak laser beam is completely absorbed. An x-ray laser in the atmosphere might therefore be able to attack an object in space because the beam is intense enough in the vicinity of the laser to bleach the air, whereas an x-ray laser in space could not attack objects within the atmosphere. This fact bodes ill for defensive space-based x-ray lasers attacked by similar lasers (or

even weaker ones) launched from the ground by the offense.

As with visible and infrared lasers, the lethality of an x-ray laser is subject to large uncertainties. The proper order of magnitude for the amount of x-ray energy per square centimeter that needs to be deposited on the side of a booster to damage it can be estimated fairly easily. But the actual hardness of a booster would depend on many design details in a way that is not fully understood at this time. A simple calculation[6] indicates that 20 kJ/cm² is a reasonable number to take for the hardness of a booster. This is about the same as for impulse kill by visible laser. An RV would be harder, and a satellite softer.

Orbital Defense Concept

The "perfect" x-ray laser whose characteristics were deduced above would be capable of intercepting a booster from geosynchronous orbit 40,000 km above the Earth. One laser would be needed for each Soviet booster. At lower altitudes, the rods surrounding the bomb could be gathered into several bundles and each bundle aimed at a different booster. At these lower altitudes, though, the absentee problem means that roughly one x-ray laser device would still need to be placed in orbit for each Soviet booster. Though the x-ray lasers are small and light compared to a chemical laser, the cost tradeoff involved in launching a new laser every time the Soviets deploy a new ICBM is obviously not a tolerable one for the United States.

The x-ray laser can attack the boosters after they have left the protective atmosphere but before burnout. Simultaneous launch of all Soviet boosters is not a problem for x-ray lasers in the way it is a problem for chemical lasers that must dwell on each target before passing on to the next. Fast-burn boosters are likewise not a crippling problem for an orbiting x-ray laser system *unless* they burn out before they leave the atmosphere. Other countermeasures, most notably the vulnerability of U.S. orbital x-ray lasers to Soviet x-ray lasers, are treated in section 5.

Pop-Up Defense Concept

The pop-up concept represents an attempt to avoid the one-laser-per-booster cost exchange and the vulnerability associated with basing the lasers in space (though crucial sensors remain space-based even in the pop-up scheme). The small size and light weight of the bomb-pumped lasers makes it possible to consider basing them on the ground and launching them into space upon warning of Soviet booster launch.

Figure 3.9 shows why basing the pop-up lasers in the United States is not practical. During the 200 seconds or so of burn time of a Soviet MX-

Figure 3.9

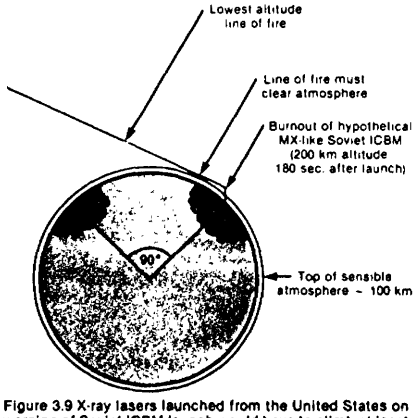


Figure 3.9 X-ray lasers launched from the United States on warning of Soviet ICBM launch would have to climb at least as high as the line of fire shown in the figure within three minutes to intercept an MX-like Soviet ICBM. Such a huge fast-acceleration defensive booster would be many times larger than the Saturn V that took astronauts to the moon.
Source: Author

[6]A mallet or soft hammer blow applies an impulse per unit area of about 10 ktaps (0.5 kg hammer head, 5 m/sec striking velocity, 3 cm radius contact area; 1 tap = 1 dyne-sec/cm²) To apply an impulse of this strength to the entire side of an ICBM booster requires a fluence F, whose order of magnitude can be estimated as follows: The cold mass absorption length (a) for 1nm x-rays is about 0.5 milligrams/cm². If all the energy absorbed by the paper-thin absorbing layer were converted to kinetic energy, the boil-off velocity would be $(F/a)^{1/2}$, meaning an impulse per unit area of order $(Fa)^{1/2}$. 10 ktaps is therefore produced if F = 20 kJ/cm².

In reality, not all the deposited energy couples to the booster in this way. A more careful calculation of this lessened coupling has been performed by Hans Bethe (private communication).

like ICBM, the U.S.-based pop-up lasers would have to climb high enough to see the Soviet boosters over the Earth's horizon and have a line-of-fire unobstructed by the absorbing atmosphere. Climbing so high so fast requires a booster for the x-ray lasers that is many thousands of times larger than the Saturn V rocket that carried U.S. astronauts to the Moon.

If the British Government allowed the U.S. Government to base x-ray lasers in the United Kingdom, the lasers would be separated from Soviet ICBM silos by only 45 degrees of arc rather than 90 degrees as with U.S. basing. Even so, popping up to attack an MX-like Soviet booster would require an enormous fast-burn booster for the x-ray laser and would put it into position to attack the Soviet booster only seconds before burnout. If the Soviets depressed the trajectory or shortened the burn time of the offensive booster very slightly, or if the United States suffered any delay whatsoever in launching the defensive boosters after Soviet launch (instantaneous warning), this hypothetical U.K.-based system would be useless.

A final possibility would be launch of defensive lasers from submarines stationed immediately off Soviet coasts—in the Kara Sea or Sea of Okhotsk, separated from Soviet silos by about 30 degrees of arc—on SLBM-sized fast-burn boosters. With instantaneous warning, a sea-based laser might be able to climb to firing position a few seconds before burnout of a Soviet MX-like ICBM and would enjoy almost an entire minute of visibility to a slow-burning, high-burnout-altitude booster like the SS-18. Because of the short range, each bomb-pumped laser of the perfect design described above could attack many (over 100) boosters using many individual lasing rods. Such efficiency could well be essential, since a submarine cannot launch all its missiles simultaneously and might only be able to fire one defensive missile in the required few seconds. If the MX-like Soviet boosters were flown on slightly depressed trajections, if warning were not communicated to the submerged submarine promptly, if a human decision to launch defensive missiles were required, or if the Soviets deployed boosters that burned faster than MX, the sub-launched system would be nullified. Last, submarine patrol very near to Soviet shores suggests the possibility of attacking the submarine with shore-based nuclear missiles as soon as its position has been revealed by the first defensive launch. Other countermeasures are discussed in Section 5.

3.4 SPACE-BASED PARTICLE BEAMS

Beams of atomic particles would deposit their energy within the first few centimeters of the target rather than at the very surface as with lasers. The effects of irradiation with the particle beam could be rather complex and subtle and would probably depend on design details of the attacking Soviet booster. The result is uncertainty of several factors of ten in the effective hardness of an ICBM booster to beam weapon irradiation.

Only charged particles can be accelerated to form high-energy beams, but a charged beam would bend uncontrollably in the Earth's magnetic field. (There is one theoretical exception to this statement, described below.) For this reason neutral particle beams, consisting of atomic hydrogen (one electron bound to one proton), deuterium (one electron, one proton, one neutron), tritium (electron, proton, two neutrons) or other neutral atoms are considered. To produce a neutral hydrogen (H^o) beam, negative hydrogen atoms (H^-) with an extra electron are accelerated; the extra electron is removed as the beam emerges from the accelerator.

Two features of neutral particles beams dominate their promise as boost phase intercept weapons (leaving aside entirely the issue of countermeasures). The first is the uncertain lethality of the beam. The second is the fact that the beam

cannot propagate stably through even the thinnest atmosphere and must wait for an attacking booster to reach very high altitude.

Generating Neutral Particle Beams

The accelerator that accelerates the negative hydrogen ion is characterized by its current in amperes, measuring the number of hydrogen ions per second emerging from the accelerator; and by the energy of each accelerated ion in electron volts (eV; 1 eV = 1 watt per ampere). Multiplying the current by the energy gives the power of the beam, so that a l-amp beam of 100 MeV particles carries 100 MW of power. Ground-based high-current accelerators and ground-based high-energy accelerators have been built and are operated daily in laboratories. One of the challenges for neutral particle beams as weapons is that they require *both* high current *and* high energy. Another challenge is to provide multi-megawatt power sources and accelerators in a size and weight suitable for space basing.

Magnets focus and steer the beam as it emerges from the accelerator. The last step is to neutrialize the beam by passing it through a thin gas where the extra electron is stripped off in glancing collisions with the gas molecules, forming H^0 from H-. The divergence angle of the beam is determined by three factors. First, the acceleration process can give the ions a slight transverse motion as well as propelling them forward. Second, the focusing magnets bend low-energy ions more than high-energy ions, so slight differences in energy among the accelerated ions lead to divergence (unless compensated by more complicated bending systems). Third, the glancing collisions that strip off the extra electron give the H atom a sideways motion. This last source of divergence is unavoidable and, by the Heisenberg uncertainty principle, cannot be controlled or compensated. It sets a lower limit on the divergence angle achievable with this method of producing neutral particle beams. Table 3.2 shows the divergence angle resulting from this third source, assuming perfect control of the first two sources. The divergence cone from a neutral particle beam is therefore about 10 times larger than the beam from the chemical laser of section 3.1 and 10 times smaller than from the x-ray laser of section 3.3.

A 100 MeV, 0.5 amp neutral tritium (T^0) beam thus directs 50 MW of power into a cone of divergence angle 2 microradians, producing a spot 10 meters across at 5 Mm range. A target within this spot receives only 65 watts/cm², requiring 1.5 seconds of dwell time to deposit only 100 J/cm².

Table 3.2.—Neutral Particle Beam Divergence Angle

	H^0	T^0
100 MeV	3.6 microradians	2.0
500 MeV	1.4	1.0

Divergence angle introduced by stripping electrons from a beam of negative hydrogen or tritium ions to produce a neutral beam. This source of divergence is an unavoidable consequence of the Heisenberg uncertainty principle applied to the sudden stripping of the electron. If the satellite-based accelerator of the negative ions were absolutely perfect, this amount of divergence would remain.

SOURCE: Author

Booster Vulnerability to Particle Beams

As soon as the neutral particle beam hits the target, the remaining electron is stripped off, leaving the energetic proton (or deuteron or triton) penetrating deeply into the target. The proton scatters electrons in its path, giving up a small amount of its energy to the electron in each collision. When it has given up all its energy, it stops. For most of its path, it deposits energy uniformly. Thus if a 100 MeV T^0 beam penetrates 4 cm into the propellant in a missile, it deposits about 25 MeV along each cm. Protons penetrate more deeply than tritons of the same energy, and all particles penetrate more deeply as they are given more energy (table 3.3).

Table 3.3.—Penetration Range of Neutral Particle Beams Into Matter (in centimeters)

	H^0		T^0	
	100 MeV	250 MeV	100 MeV	250 MeV
Solid propellant or high explosive (density 1.0 gm/cm³)	9.5	46.6	4.2	20.2
Aluminum	3.5	17.2	1.6	7.6
Lead	0.8	3.9	0.4	1.7

SOURCE: Author

Figure 3.10

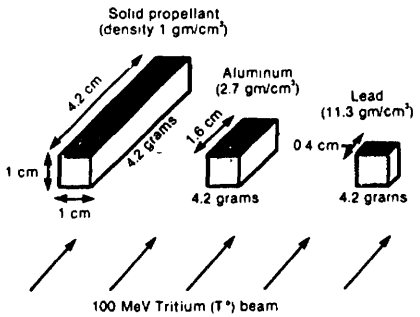


Figure 3.10 A neutral particle beam penetrates farther into an aluminum target than into a lead target but deposits the same energy per gram. Though the energy per gram needed to melt aluminum is well known, the utility of particle beam BMD concepts rests on the less certain destructive effects at lower levels of irradiation. Source: Author

Table 3.4.—Effects of Particle Beam Irradiation

Harmful effect	Energy deposition (Joules per gram)
Disruption of electronics	0.01—1.0
Destruction of electronics	10
Detonation of propellants, high explosive	200
Softening of uranium and plutonium	hundreds
Melting of aluminum	1,000

Approximate energy deposition (radiation dose) required to produce various harmful effects in components of a missile booster and its payload. Many other effects, such as melting of glue and plastic and rate-dependent effects, might also be important

SOURCE: Author

The target electrons that recoil from collisions with beam particles eventualy stop, and their energy appears as heat. The 100 MeV T° beam described above, depositing 100 J/cm² on an aluminum target, penetrates to a depth of 1.6 cm. The 1.6 cubic centimeter volume of aluminum that absorbs this 100 joules of energy weighs about 4 grams. The effect of the beam is therefore to deposit about 25 joules per gram throughout the first 1.6 cm of the target. The penetration depth is inversely proportional to the density of the absorbing material, so the same beam on a lead target would not penetrate as far but would deposit the same energy *per gram* as it did in aluminum (fig. 3.10).

The destructive effects of penetrating particle beams are therefore expressed in joules/gram deposited within the target rather than in joules/cm² on the surface of the target as with lasers. Table 3.4 shows the energy deposition needed to produce certain harmful effects. Melting the target is straightforward, but for the other effects at lower levels of irradiation the criteria are less clear. Heat effects in solid booster propellants and in the high explosive and special nuclear materials in warheads depend on the design of the target. Effects on electronics, particularly transient disruption of computer circuits when electrons are scattered by a passing proton, are poorly known and doubtless quite complicated and specific to the target. Other components not shown in table 3.4 —plastics, glue, guidance sensors— make for a very complicated analysis. What is more, the particle beam might have to suffer the attenuation of passage through, say, two layers of aluminum and a layer of plastic before reaching a sensitive component.

Uncertainties in the destructive or disruptive effects of small amounts of radiation from a particle beam weapon is the principal obstacle to stating what energy, current, and divergence angle would make this concept a candidate for boost-phase intercept.

Shielding to protect components from a neutral particle beam would necessarily be heavy but could still be an attractive countermeasure. It is discussed in Section 5.

An Orbiting Neutral Particle Beam System

A critical limitation of neutral particle beams is that they cannot be aimed through even the thinnest atmosphere—air so thin that even the x-ray laser beam could pass through easily. A neutral beam could not attack a Soviet booster until the booster reached at least 160 km altitude (versus about 80 km for the x-ray laser)[7]. Collisions

[7]The stripping cross section on oxygen is about 1.5 megabarns. Elastic scattering can also be important for beam loss, since the RMS scattering angle can be larger than the beam divergence. The author is indebted to Dr. George Guillespe of Physical Dynamics, Inc., in La Jolla for results of his Born approximation cross section calculations

between air molecules and H^0 strip the electron from the H^0, and gradually all the remaining protons spiral off the beam axis into 200 km wide circles under the action of the earth's magnetic field.

An MX-like Soviet booster could be attacked between 160 km altitude and burnout at 200 km, a period of about 10 seconds. This short attack window means that the neutral beam cannot afford to dwell for long on each booster.

It is impossible to state with confidence the resilience of an ICBM booster to irradiation with a neutral particle beam. But it is likely that faith would have to be placed in degradation of electronics and other subtle effects, rather than in gross structural damage, for the beam weapon to stand a chance as an economical defense system (ignoring the issue of countermeasures entirely).

Consider again a battle station producing a 0.5 ampere beam of 100 MeV tritium (T^0) atoms with 2 microradian divergence. This beam carries 400 watts/cm² at 2 megameters range. To do structural damage to the outer few centimeters of a missile's body might take some 2 kJ/cm² (depositing 500 J/gm in 1.6 cm depth of aluminum, for instance), requiring 5 seconds of dwell time at this range. Since the available dwell time is only about 10 seconds, each beam could handle only two boosters. With a constellation size of almost 100 for 2 Mm range (fig. 3.4), this kill criterion results in a preposterous system where the U.S. deploys 50 space-based accelerators for every one Soviet booster deployed in one region of the U.S.S.R.

If the assumed Soviet booster hardness is reduced by 100 times, corresponding perhaps to transient upset of unshielded electronics, each satellite can destroy 200 boosters at 2 Mm range, meaning an overall tradeoff of one U.S. accelerator deployed for each two Soviet boosters deployed. Alternatively, the constellation can be thinned out to an effective range of 5 Mm, where each satellite at this range can destroy only 32 boosters but the constellation size is only about 16—still a one-to-two trade of battle stations for Soviet boosters. Such a system scarcely seems promising in terms of cost exchange.

Obviously the neutral particle beam would stand no chance of intercepting a fast-burn booster that burns out well within the protective atmosphere. Even an MX-like booster that flew a slightly depressed trajectory would be invulnerable.

A Theoretical Electron Beam System

Physical theory[8] holds out the prospect of one other type of beam besides the neutral particle beam. Under certain circumstances, an electron beam might be able to propagate through the extremely thin air of near-earth space without bending. In this scheme, a laser beam would first remove electrons from air molecules in a thin channel stretching from the battle station to the target, leaving a tube of free electrons and positive ions. The high-energy, high-current electron beam would then be injected into the channel. The beam electrons would quickly repel the free electrons from the channel, leaving the beam propagating down a positively charged tube. The attractive positive charge would prevent the electrons from bending off the beam path under the influence of the geomagnetic field and would also prevent the mutual repulsion of electrons within the beam from causing the beam to diverge. The result would be straight-line propagation to the target, where their effect would be similar in most respects to the neutral particle beam. This scheme will not work for a proton beam.

The physics of intense beam propagation through thin gases is so complex that experiments will be needed to determine whether this concept is even feasible in principle. If so, the concept would resemble the neutral particle beam, with the added requirement for the channel-boring laser and perhaps the ability to intercept boosters at slightly lower altitudes than the neutral counterpart.

[8] R. B. Miller, *The Physics of Intense Charged Particle Beams*, New York, 1982, ch. 5.

3.5 SPACE-BASED KINETIC ENERGY WEAPONS

Kinetic energy is the name given to the energy of a moving projectile. Use of this term makes ordinary weapons using aimed projectiles into "directed kinetic energy" weapons.

The phenomenology of high-velocity collisions between a projectile and a structure like a booster is surprisingly complex, but in general lethality is not an issue for kinetic energy boost phase intercept concepts. Rather, the problem is getting the projectile from its satellite base to the ascending booster in time to make an intercept. Schemes where the projectile is carried by a small rocket launched from the satellite suffer most directly (leaving aside countermeasures) from a combination of the large number and large size of the rockets needed for adequate coverage. In particular, the most conspicuous public example of the kinetic energy approach, the High Frontier Project's Global Ballistic Missile Defense (GBMD) concept,[9] has extremely limited capability for boost phase intercept of current Soviet ICBMs and would have no capability at all against a future generation of MX-like boosters.

Kinetic Energy Concepts

Rocket attack of ICBM boosters is obviously not as novel as beam attack, but it entails rather more complexity than appears at first blush. The rocket needs radio or other guidance by long-range sensors on its carrier satellite (or other satellites) to direct it to the vicinity of its target, since it is impractical to put a long-range sensor on each rocket. Once in the vicinity of the target booster, the interceptor needs some form of terminal homing sensor and rather sizeable divert rocket motors. Homing on the plume of the ICBM booster is not straightforward, since attacking the plume will obviously not harm the booster: the booster body must be located in relation to the plume. These complications introduce opportunities for offensive countermeasures.

An alternative to rocket propulsion would be to expel the homing vehicles at high velocity from a gun. So-called rail guns use a clever scheme to convert electrical energy to projectile kinetic energy. Since a 10 kilogram projectile ejected with 5 km/sec velocity carries 125 megajoules of energy (the amount of energy expended by a 25 megawatt chemical laser in 5 seconds of dwell on a booster), the power requirements of the gun schemes are imposing. Providing chemical fuel or explosives to power a gun therefore involves the same magnitude of on-orbit weight as the chemical laser.

Doing away with the homing sensor and replacing the guided projectile with many small fragments is not an attractive alternative, since the needed fragments end up weighing far more than the guided projectile.

The Importance of Projectile Velocity

In the 300 or so seconds from launch to burnout of a slow-burning booster like the SS-18, the defensive rocket or other projectile must fly from its satellite to the path of the booster. Such a booster burns out at about 400 km altitude, so if the projectile wishes to use the entire 300 seconds of boost phase to travel to its quarry, it must make its intercept at 400 km altitude.

Suppose now that the projectile's rocket or gun launcher can give it a maximum velocity of 5 km/sec with respect to the carrier satellite. In the 300 seconds of available travel time to its target, the projectile cannot fly more than (5 km/sec) × (300 sec) = 1.5 Mm from its carrier. Each carrier therefore has an effective range of 1.5 Mm (fig. 3.11a).

Referring to figure 3.4, a constellation of about 240 carrier satellites are needed for continuous coverage of the Soviet Union. Since Soviet ICBMs are spread over much of the country, 10 or so of the carrier satellites might be able to participate in a defensive engagement. The absentee ratio is therefore about 24. The 10 satellites over the U.S.S.R. at the moment of a massive Soviet attack need to be able to handle all 1,400 boosters, meaning each satellite needs to carry 140 projectiles.

An idealized rocket accelerating a 15 kg guided projectile to 5 km/sec velocity would need to weigh about 80 kg (a real rocket with this capa-

[9] General Daniel O. Graham, *The Non-Nuclear Defense of Cities: The High Frontier Space-Based Defense Against ICBM Attack* (Cambridge: Abt Books, 1983).

Figure 3.11(a)

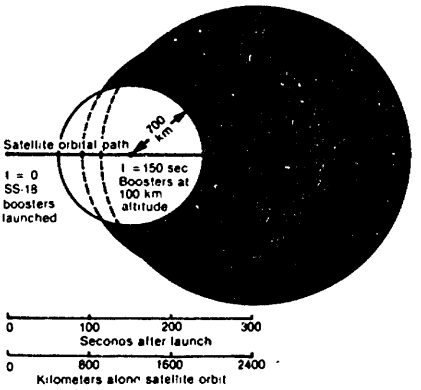
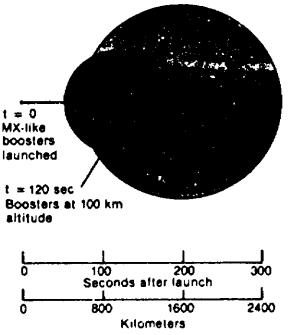


Figure 3.11(b)



(b) Same as (a), except the target is the faster-burning MX.

Figure 3.11 View from above (looking down on earth) of coverage by a satellite carrying kinetic energy boost-phase intercept vehicles. The satellite is deployed in a 400 km orbit. At time t = 0, offensive boosters are launched. The satellite can make intercepts by shooting downward or wait until the boosters rise to their burnout altitude and fire nearer to the horizontal. The longer after launch the intercept is made, the farther the rocket intercept vehicles can travel from the satellite to make the intercept. Smaller circles thus correspond to downward firing, larger circles to horizontal firing. The satellite moves from left to right in accordance with its 8 km/sec orbital velocity. The area enclosed by all the circles taken together gives the total coverage of the satellite and determines how many satellites are needed in the worldwide constellation for continuous coverage of opposing ICBM fields. All dimensions are to same scale.
(a) The satellite-based kinetic energy interceptors are capable of 5 km/sec velocity relative to the satellite. The attack is on a slow-burning Soviet SS-18.

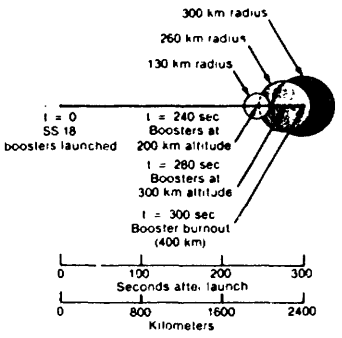
bility would weigh more like 200 kg). Each carrier satellite must therefore weigh (140) × (80) = 11,000 kg. Less than twice this weight can be carried by the space shuttle into the appropriate orbits, so establishing the total 240 satellite constellation requires over 120 shuttle launches in this highly idealized model with idealized rockets and weightless carrier satellites. (A more careful estimation of interceptor design would more than double this load.)

From this baseline, we can consider five excursions:

1. Suppose the velocity capability of the interceptor is doubled to 10 km/sec, doubling the effective flyout range to 3 Mm. At this range, 48 satellites complete the constellation, with perhaps as many as eight of them in position to participate in the engagement. Each of the eight satellites must handle 175 Soviet boosters.

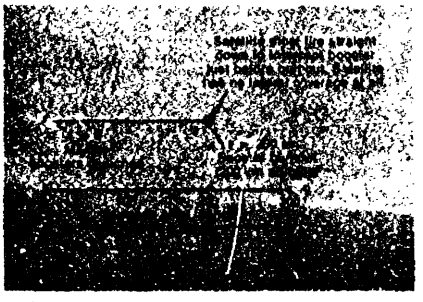
   Doubling the velocity capability more than doubles the weight of the rocket required. The reason is simple: to increase the velocity requires more propellant, and the extra propellant must itself be accelerated, requiring yet more propellant. The rocket weight thus grows exponentially with velocity capability. The idealized 10 km/sec rocket weighs 420 kg. Each satellite carrying 175 rockets then weighs 75,000 kg and requires some five shuttle launches to orbit. The result is that over 200 shuttle launches are required to orbit the entire (idealized) defense system. Increasing the velocity capability is therefore no escape from large on-orbit weights.
2. The current Soviet ICBM force consists largely of slow-burning liquid-fueled boosters distributed widely over the Soviet Union. Consider the consequences for the U.S. kinetic energy defense system if the Soviets de-

Figure 3.11(c)



(c) The High Frontier Global Ballistic Missile Defense (GBMD) concept, with intercept vehicles capable of only 1 km/sec velocity relative to the satellite. Intercept of SS-18. In the actual High Frontier proposal, the satellites are in 600 km orbits, giving them even less coverage than shown here.

Figure 3.11(d)



(d) The High Frontier concept has no capability whatsoever for boost-phase intercept of MX.

ploy 100 faster-burning MX-like boosters in one region of the country, so that defensive interceptors have less time to fly to their targets and only one satellite overhead participates in the engagement. MX burns out 200 seconds after launch, so each satellite has an effective range of 1 Mm, requiring a constellation of 400 satellites (fig. 3.11b). Each satellite must carry the 100 80-kg rockets needed to handle the attack. An exchange ratio of four 8,000 kg U.S. defensive satellites for every Soviet offensive booster deployed is surely an economic advantage for the U.S.S.R.

3. Soviet deployment of 1,000 Midgetman-like boosters would require a compensating deployment of 400 U.S. satellites, each weighing at least 80,000 kg. A system that forces the United States to such a response is clearly absurd.
4. Soviet fast-burn boosters would be totally immune to the kinetic energy defense system. An interceptor on a satellite in 400 km orbit (lower orbits shorten satellite lifetimes because of atmospheric drag) could not even descend straight down to the fast-burn booster's 100 km burnout altitude in the required 50 seconds, much less have any lateral radius of action.
5. Intercepting SS-18 or MX post-boost vehicles is clearly easier, from the point of view of flyout velocities, than boost-phase intercept. Satellites at 700 km or so altitude would have 500 seconds to fly out to meet the bus when it ascended to their altitude, giving a 2.5 Mm lethal radius.

In conclusion, a rocket-propelled kinetic energy system acting against today's Soviet ICBM arsenal (with no Soviet countermeasures) would require many heavy satellites and would be a dubious investment for the U.S. Soviet deployment of MX-like or Midgetman-like boosters would nullify the United States defense or force the U.S. to large investments in new satellites.

Analysis of the High Frontier Concept

The High Frontier Program[10] proposes a Global Ballistic Missile Defense (GBMD) using rocket propelled interceptors for boost phase intercept. This concept claims to have some utility, at least against the present Soviet ICBM arsenal.

The concept consists of 432 satellites (24 planes of 18 satellites in circular orbits inclined 65 degrees) at an altitude of 600 km. A velocity

[10]Ibid.

capability of 1 km/sec relative to the satellite ("truck") is attributed to the interceptor. The interceptors are apparently command guided to the vicinity of the target. The homing sensor is not specified, but short wave infrared homing on the hot rocket plume is implied.

Consider this concept defending against the SS-18 in its boost phase. Since the SS-18 burns out at 400 km altitude 300 seconds after launch, each GBMD satellite has a 0.3 Mm radius of action. Since the satellites are deployed at 600 km altitude, the interceptor must descend 200 km to make an intercept just before burnout, resulting in a lateral radius of action of 0.22 Mm (compare fig. 3.11c, where the satellites are assumed deployed at 400 km altitude). With a range this small, thousands of satellites would be needed worldwide for continuous coverage of Soviet ICBM fields. The High Frontier concept with only 432 satellites would therefore have meager coverage of Soviet ICBM fields.

The GBMD concept would have no capability whatsoever against an MX-like booster. Such a booster would burn out before the interceptor could reach it, even if the interceptor were fired straight down (fig. 3.11d).

It is possible that the High Frontier concept is designed for post-boost intercept rather than boost phase intercept. Its coverage for post-boost intercept, though greater than for boost-phase intercept, would still be only partial. The only example given in the description[11] of the system is of *boost phase* intercept of an SS-18, however. In this example the interceptor is launched 53 seconds *before* launch of its target booster, though no explanation is given of how the U.S. defense knows *in advance* the precise moment at which the Soviets would launch a given booster. This early launch allows the interceptor to reach its target seconds before burnout. Plume homing, a technique inappropriate for bus intercept, is also implied for the High Frontier concept. Post-boost intercept permits some RVs to be deployed on trajectories carrying them to the United States before intercept; and the entire bus, with its warheads, would continue on to the U.S. after the interceptor collision, with uncertain consequences.

It would therefore appear that the technical characteristics of the High Frontier scheme result in a defensive system of extremely limited capability for boost phase intercept of present Soviet ICBMs and no capability against future MX-like Soviet boosters, even with no Soviet effort to overcome the defense.

[11] Ibid., p. 103

3.6 MICROWAVE GENERATORS

Microwaves are short-wavelength radio waves used in radar, satellite communications, and terrestrial communications relays. A number of ideas have been conceived for generating microwaves in space and directing them towards ascending ICBM boosters. The principal technical problem with this type of BMD, generator technology aside, is the uncertain effect the microwaves would have on their target.

The microwaves would propagate through the atmosphere unattenuated at all but the highest power levels. The weapon divergence angle would be very large, producing a spot many km wide at a few hundred km range. From these considerations the following concept emerges: As Soviet ICBMs lift off from their silos, a few microwave generators in space bathe the silo fields with microwaves.

At high power levels, as in a microwave oven, microwaves cause heating in many materials. But in the BMD scheme, the divergence cone is so large that even a prodigious amount of energy emitted from the generator would lead to very small energy deposition per square centimeter on the target (millions of times less than lasers). The microwave pulse received at the booster

would resemble the high frequency component of the electromagnetic pulse (EMP) from a high-altitude nuclear detonation. However, even weak microwaves can upset sensitive circuitry if they can reach it.

A metal skin on the booster would stop the microwave pulse altogether from reaching internal electronics. The microwave defense must therefore hope that some aperture or conduit is available into the booster, whether by design (as in an antenna), inadvertence, or poor maintenance. If so, and if the electronic circuitry is not or cannot be made resistant to disruption or burnout, the part of the booster's performance dependent on those electronics (perhaps accurate guidance) would be affected.

Because of the very uncertain lethality of microwaves, deployment of space-based generators (if they can ever be built) would be a harassing tactic rather than a confident-kill ballistic missile defense.

3.7 OTHER CONCEPTS

Other directed energy concepts suitable in theory for ballistic missile defense have been broached from time to time. Some of them are listed below. It is quite possible that in a few years time a revisit to this subject will find a new panoply of concepts enjoying the front rank of discussion.

1. **Short-wavelength chemical lasers** would combine the simplicity and efficiency of the HF chemical laser with the small mirrors of the short-wavelength excimer and free-electron lasers. Though some ideas have been advanced along these lines, no laser exists which can be said to be a candidate to fulfill this theoretical promise.
2. **Explosive-pumped lasers and particle beams** are said to be under study in the Soviet Union.[12] Such devices might possibly be quite compact, each bomb generating a single huge pulse for impulse kill of a booster. All these schemes are at a very early conceptual stage.
3. **Antimatter beams** would penetrate into a target just like ordinary particle beams, except that when the antiparticle reached the end of its range it would annihilate a particle in the target, freeing a large extra amount of harmful energy. Acceleration of antimatter beams is accomplished exactly as with particle beams, and laboratory beams of antimatter have been used routinely in pure research. One important difference is that antimatter is not freely available in the universe as is matter; the antimatter for the accelerator would have to be produced by the defense system, a formidable and complex undertaking. It is not clear that the extra energy released in the target by an antimatter beam would justify the trouble of producing the beam.

[12] *Aviation Week and Space Technology*, July 28, 1980, p 47

Section 4

OTHER ESSENTIAL ELEMENTS OF A BOOST-PHASE INTERCEPT SYSTEM

The previous section treated only the defensive weapon itself, the so-called "kill mechanism." But if beam weapons ever evolve to the point where deployment is a serious possibility, other elements of the overall defensive system will emerge as equally important determinants of cost and level of protection. After all, the interceptor missile in traditional BMDs has not been the central focus of attention or technical debate since the 1950's, when it became clear that a "bullet could hit a bullet." Discussion of BMD at that point passed to the difficult issues of radar performance, data processing capability, and vulnerable basing of defensive components—issues that had nothing to do with the kill mechanism. In a similar manner, the other essential elements of a boost-phase intercept system will figure more prominently in discussion of boost-phase BMD if and when the kill mechanisms—lasers, mirrors, accelerators—are in hand. These other essential elements introduce their own technological problems and opportunities for offensive countermeasures. If traditional BMDs are any guide, provision of a kill mechanism will be just the beginning of making an efficient, robust defensive system.

4.1 TARGET SENSING

Locating and tracking an ICBM booster with enough precision to aim a directed-energy weapon is not as straightforward as is sometimes supposed. It is true that booster motors emit hundreds of kilowatts of power at short- and medium-wave infrared (SWIR and MWIR) wavelengths of a few microns. Sensors can detect these plumes at great distances from the earth. Plume sensing is used today for early warning of missile attack to support launch of bombers and airborne command posts and launch under attack of ICBMs.

To be useful for directed-energy BMD, however, the sensor must localize the booster within an area as small as the beam spot. Otherwise the beam would have to sweep wastefully back and forth over the area of uncertainty. Small divergence beams must therefore be accompanied by sensors with small angular resolution.

Diffraction limits the angular resolution of a sensor in the same way it limits the divergence angle of a laser. A large infrared telescope with 5 m diameter mirror observing MWIR booster emission at 4 micron wavelength would have angular resolution no more precise than a microradian. Such a sensor affixed to each battle station in a defensive constellation would localize ascending boosters to within a spot 5 m wide at 5 Mm range. At this range, the (illustrative) systems described in Section 3 have spot sizes: 1.5 m for the HF laser, 0.6 m for the ground based laser, 10 m for the neutral particle beam, and 100 m for the x-ray laser. Even a large infrared sensor on each battle station would therefore be inadequate for directing the laser beams at a point source of MWIR light, marginal for directing the neutral particle beam, and adequate for directing the x-ray laser. The actual situation would be worse still, since the booster is not a point source. The booster plume would be larger than the laser or particle beam spots, and the booster body would need to be located in relation to the plume to avoid wasting beam time attacking the plume.

For directed-energy weapons with small divergence angles, therefore, sensing the conspicuous rocket plume is inadequate. Another kind of sensor must be introduced into the BMD system. For finer angular resolution one looks to shorter wavelengths, in the visible or ultraviolet. At these wavelengths the sensor must provide its own illumination. A so-called laser radar or ladar is the only practical solution. In a ladar, a low-power

visible or ultraviolet laser shines on the booster body, and a telescope on board the battle station senses the reflected light.

Besides the annoyance of a new laser and new sensor, the necessary introduction of ladar into the boost-phase system creates opportunities for the defense to spoof and blind the offensive sensor.

Kinetic energy systems do not need precision long-range sensing, since the rocket or guided projectile homes on the target when it comes within short range. The terminal homing might involve deducing the location of the booster body in relation to its MWIR plume, homing on low-power laser light shined from a defensive satellite and reflected from the target, or some other method. These homing methods are susceptible to countermeasures

Though this Background Paper treats only intercept of the booster proper, it is worthwhile pausing to consider tracking of the post boost vehicle or bus. The low thrust levels of the post boost vehicles's rocket motors their intermittent operation, the possibility of dimming them with propellant additives, and the possibility of building decoys with small rocket motors all suggest that MWIR plume sensing is not practical for post boost intercept. The alternatives are ladar or radar, suggesting again many opportunities for countermeasures.

4.2 AIMING AND POINTING

The directed-energy beam must be aimed and stabilized as accurately as it is collimated. If the beam waves around too much, the effective divergence increases, and the beam wastes energy missing the target. The mirrors or other mechanism steering the beam must be stabilized despite vibrations in the battle station caused by the beam's large power source.

In the 15 milliseconds the beam takes to travel from the battle station to a booster 5 Mm away, the booster moves about 50 m. A narrow beam must therefore lead the target. In one second of dwell time, the target moves several km; the beam must remain on the target, sweeping through the sky at the necessary angular rate while still maintaining its aim and jitter control.

4.3 INTERCEPT CONFIRMATION

A desirable, though perhaps not essential, function of BMD systems is confirmation that an attempted intercept succeeded. This function is sometimes called "kill assessment." Intercept confirmation would allow the beam to move onto subsequent boosters with more than a statistical estimate that its previous task was accomplished. Structural damage to the booster would presumably be revealed by an erratic course or burn pattern, though it might be difficult to say in advance exactly what the sensor's view of the wounded booster would be. Subtle damage inflicted by a particle beam or microwave generator might not be visible. Damage to a bus would be difficult to assess and interpret if the debris, including RVs (perhaps arranged by the offense to separate from the bus under extreme circumstances), continue on their ballistic course to the continental United States.

Related to intercept confirmation, and ultimately more serious, is the question of determining whether the beam is missing the target (perhaps by slight misalignment of sensor and beam boresights, miscalibration of aiming mechanisms, etc.) and, if so, by how much and in what direction. It might be possible to observe a glowing column of air where a laser beam passes through the at-

mosphere. Some clever but elaborate schemes have been devised to track a neutral particle beam. Obviously each new complication added to the defensive system potentially creates new opportunities for offensive countermeasures.

4.4 COMMAND AND CONTROL

The crucial infrastructure of command and control of a complex system is always the last to take shape, since it integrates the workings of all the separate components. It is easy to ignore the difficulty of accomplishing this last step at this early stage when the other components of a boost phase system are not yet remotely in hand. The command and control system of a boost-phase intercept system would comprise communications links among its far-flung components, data processing to support sensors and battle station operations, and "battle management" software incorporating all the instructions and decisions needed to run the defensive engagement and to coordinate the defense with U.S. offensive forces.

Communications and data processing are two areas of technology where there is the least pessimism—looking two or so decades into the future when boost-phase systems could presumably be deployed—that technology will be able to meet the needs of directed-energy defenses. Compact, lightweight, and rapid data processing hardware is virtually assured, though interesting questions attend on hardening, reliability, and lifetime in space. Software would be expensive and would introduce issues of reliability and security from programmer sabotage. Satellite-to-satellite communication via extremely high frequency radio and laser offers high data rates and virtual immunity to jamming from earth or from space.

Command and control for BMD does introduce two interesting issues to which technology cannot provide an answer. The first is the impossibility of testing the whole defense system from end to end in a realistic wartime setting. Unlike the air defense systems of World War II, which learned through attack after attack to exact kill rates of several percent, the BMD system would have to work near perfectly the very first time it was used. The second issue is the likely need for the defense to activate itself autonomously, since there would be no more than a minute for human decision.

4.5 SELF-DEFENSE

Consideration of anti-satellite (ASAT) attack (see Section 5.1), and analogy with traditional BMD systems (where vulnerability of key radars, data processors, and other components is usually the chief limitation on defense performance) suggest that self-defense mechanisms could well end up being a large part of the defense system. These mechanisms could include shields, escort weapons, and countermeasures to ASAT sensors. Unless and until a credible overall approach to satellite survivability is found, one cannot specify the needed hardware.

Ground-based BMD lasers and pop-up x-ray lasers would obviously need to be protected from precursor attack by cruise missiles and other delivery systems.

4.6 POWER SOURCES

Chemical lasers, x-ray lasers, and rocket-propelled kinetic-energy interceptors have power sources integral to the weapon, but excimer lasers, free electron lasers, neutral particle beams, and rail guns would need sources of electrical power and the equally important means to convert electricity into a form usable by the weapon ("power conditioning"). Space basing obviously complicates the task. Large commercial power plants on the ground produce about 1,000 MW of power, and directed energy weapons might require hundreds of MW. On the other hand, the power plants on defensive satellites need not work reliably for many years but only once for a short time, and they need not be very highly efficient. The three alternatives for space power are fuel burning, explosives, and nuclear power. Starting up a large power source in seconds from a condition of dormancy poses some interesting design issues.

Section 5

COUNTERMEASURES TO BOOST-PHASE INTERCEPT

Countermeasures that limit the effectiveness of traditional ballistic missile defenses—decoys, radar blackout, defense suppression, etc.—are well known. A comparable set of countermeasures, no less daunting for being less familiar, faces the designer of boost-phase defenses.

The need to resort to countermeasures imposes a cost on the offense. This cost is measured in money to build more or specialized offensive hardware, but also in the time needed to do so, in constraints upon the type of attack the offense can incorporate in its nuclear planning, and in the confidence with which it can predict a "successful" outcome of the strike.

Every BMD system actually proposed for deployment would be accompanied, at least ideally, by, first, an analysis of its degradation in the face of an improving Soviet offense and, second, by an analysis of how much it would cost for the United States to improve its defense in such a way as to avoid being overcome.[1]

[1] See *Ballistic Missile Defense*, ed. Ashton B. Carter and David N. Schwartz (The Brookings Institution, 1984), ch. 4.

Figure 5.1

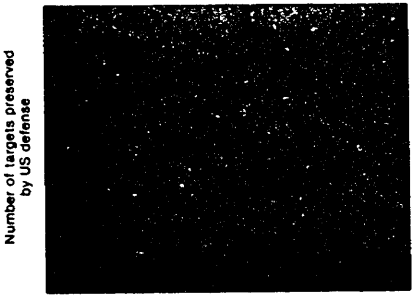


Fig. 5.1. Schematic drawdown curve, showing how the performance of a BMD system degrades as the size and sophistication of the attacking force increase.

Figure 5.2

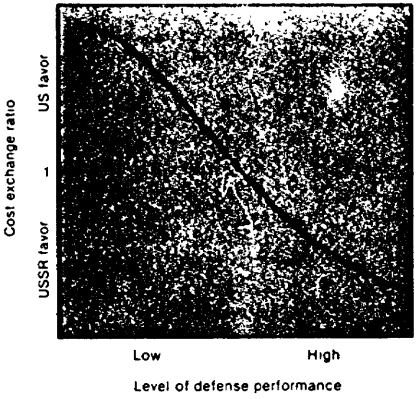


Fig. 5.2. The marginal cost exchange ratio measures the outcome of a race between the Soviet offense to enhance its penetration and a U.S. defense to maintain its level of protection. In general, modest defense goals (e.g., "preserve 40 percent of the targets") are easier to sustain than high goals ("preserve 95 percent of the targets") against improvements in Soviet offensive forces, including deployment of countermeasures.

The first analysis would be expressed in a drawdown curve such as that shown in figure 5.1. The Soviets can overcome the defense and destroy a large number of U.S. targets, but to do so the Soviets must "pay" an "attack price."

The second analysis would be encapsulated in the cost exchange ratio. The marginal cost exchange might be defined as follows: "Assume that in the year 2000 the U.S. defense and Soviet offense have evolved so that each has a certain level of effectiveness. Suppose the Soviets wish to improve their position and the U.S. resolves to maintain the status quo. Which side spends more in the competition?" For example, suppose every time the Soviets add 100 ICBMs to their arsenal, the United States has to add 20 satellites to its defensive constellation to intercept them: Which costs more, 100 ICBMs or 20 satellites?

In general, high levels of defense performance are harder to enforce in the face of offensive improvements than low levels: this important fact is shown schematically in figure 5.2 (see also Section 8.2).

All of the boost-phase intercept schemes discussed in this report are in such an early stage of conceptualization that nothing remotely like the analyses represented by Figures 5.1 and 5.2 can be done for them. Nonetheless, countermeasures are known for every boost-phase system devised, and in many cases simple heuristic estimates of the cost tradeoffs are suggestive.

Technical experts disagree not so much about the facts and calculations underlying these countermeasures as about the interpretation to be given to them. Should an apparently fatal flaw uncovered at this early stage of study of a defensive concept be decisive, or should work (and the inevitable expectations that accompany it) continue on the chance that a new idea will turn up to rescue the concept? Would the Soviets really resort to a subtle tactic or exotic piece of hardware as a confident basis for their nuclear policy? Some analysts see BMD as a way of "forcing" the Soviets to take a certain direction in their pursuit of the arms race, e.g., away from large, slow-burning MIRVd boosters to single-warhead Midgetman-like boosters. In this view, defeat of the BMD is purchased at the price of a theoretically more stable and desirable Soviet offensive posture. All these questions of judgment loom large in making a final assessment of a given countermeasure.

5.1 ANTI-SATELLITE (ASAT) ATTACK, INCLUDING DIRECTED-ENERGY OFFENSE

All boost-phase intercept BMD concepts have crucial components based in space. Even a pop-up defense would need warning and very probably target acquisition sensors on satellites over the Soviet Union. Ground-based laser defenses would have mirrors and sensors—their most fragile components—in space. Vulnerability of these satellites is a cardinal concern because their orbits are completely predictable (they are in effect fixed targets), they are impractical to harden, conceal, or proliferate to any significant degree, and because successful development of effective directed-energy BMD weapons virtually presupposes development of potent anti-satellite (ASAT) weapons. ASAT is the clear boost-phase analogue of familiar defense suppression tactics against traditional BMDs, where attack is first made upon the defensive deployment (especially fixed radars) and then upon the defended targets.

The interplay of ASAT techniques—missiles (nuclear or conventional), space mines, directed energy—and satellite defense (DSAT) techniques is a complex one. It is difficult to generalize, but in the specific case of large battle stations in low-earth orbit it would seem that the advantage is very likely to lie with ASAT, not DSAT. For one thing, the offense need not destroy a large number of defensive satellites, but only "cut a hole" in the defensive constellation. Second, the traditional military refuges all offer complications: concealment from radar, optical, infrared, and electronic detection, while possibly successful for small payloads in supersynchronous orbits, is impractical for large, complex spacecraft at most a few thousand km from the earth's surface; decoy satellites must generate heat, stationkeep, and give status reports, and they are in any event only useful if the ASAT designer is somehow restrained (perhaps by cost) from shooting at all suspicious objects; hardening imposes weight penalties, and massive shields could interfere with the constant surveillance and instant response required of the defense; proliferation is useless for expensive satellites facing inexpensive ASAT methods. As a consequence, discussions of DSAT for BMD battle stations usually emphasize large keep-out zones around the satellites and active self-defense. A third reason why ASAT is likely to prevail over DSAT is that possession by the offense of the same type of directed energy satellites used by the BMD probably assures successful first

strike. Fourth, the Soviets would pick the time and sequence of their attack, and it would occur over Soviet territory.

Two rather novel ASAT threats are worthy of note. The first is the x-ray laser itself. The x-ray laser, if it could be developed, would constitute a powerful space mine. Because of its long range, it could lurk thousands of km from its quarry. The Soviets might also launch x-ray lasers a few seconds before launch of their main attack. Recall that the well-known phenomenon of bleaching (see Section 3.3) would probably allow such x-ray lasers to shoot out of the atmosphere at a U.S. x-ray laser defense, but the U.S. x-ray lasers could not shoot down into the atmosphere at the ascending lasers.

A second ASAT tactic, discussed for many years, imagines the Soviet Union exploding nuclear weapons at high altitudes in peacetime with the intent of shortening the orbital lifetimes of the U.S. defensive satellites. The nuclear bursts inject further radiation into the van Allen belts that circle the earth's equator from about 1,500 to 10,000 km altitude. Satellites (more likely carrying sensors than weapons at these altitudes) passing through the belts accumulate a radiation dose that gradually degrades electronics, sensors, and optical surfaces. This possibility, if taken seriously, would require defensive satellites designed to withstand rather substantial accumulated radiation doses.

A detailed treatment of the ASAT problem is beyond the scope of this Background Paper. The following "parable" illustrates some of the problems encountered in trying to ensure the survivability of a defensive constellation, taking the 20 MW HF lasers of Section 3.1 as an example.

The United States deploys the HF lasers in this hypothetical system in low orbits at 1,000 km altitude. Higher altitude would place them too far from their targets. This is unfortunate: higher altitude (say, between 2,000 km and semisynchronous orbit at 20,000 km) would move the satellites further from ground-based ASAT weapons and put them into lesser-used orbits where staking out a sanctuary would involve less interference with foreign spacecraft.

Suppose the battle station designers have succeeded in the considerable task of making the satellites resilient to multi-megaton nuclear space mines (bombs, not x-ray lasers) as little as 100 km away. To keep all Soviet spacecraft (i.e., all potential mines) at least 100 km away, the United States claims for itself the orbital band between 900 and 1,100 km altitude. Perhaps the Soviets are awarded some other orbital zone for their own military purposes. The United States establishes the following rules in its zone: 1) No foreign spacecraft may transit the zone without prearrangement; 2) All transiting vehicles must remain at least 100 km from all U.S. battle stations, passing through a "hole" in the constellation; 3) Foreign spacecraft failing to obey these rules may be destroyed by the U.S. lasers.

Consider first a Soviet kinetic energy ASAT deployed at 1,100 km altitude, just outside the U.S. keepout zone. Suppose the rocket interceptors on the Soviet satellites have the same propulsive capacity—one km/sec—as the proposed High Frontier Global BMD system. The Soviet ASATs are then just 100 seconds away from the U.S. lasers. The U.S. lasers must therefore be very vigilant to avoid surprise attack. Fortunately, at 100 km range the 20 MW laser with 10 m mirror would burn up even a heavily hardened ASAT rocket in short order. Since starting up the main laser for self-defense might be awkward, wasteful of fuel, or time consuming, each U.S. battle station might be escorted by a satellite carrying a smaller laser or rockets for self-defense.

A constellation of Soviet 20 MW, 10 m HF lasers (the same technology as the U.S. lasers) at 1,100 km is another matter. These lasers could attack the U.S. lasers seconds before launch of a Soviet ICBM attack. The United States would have to keep these Soviet spacecraft *thousands* of km away from the U.S. constellation. That is, the United States would have to dominate near-earth space. Suppose the United States does so.

Now the Soviets build a fleet of pop-up x-ray lasers. These lasers climb to 100 km or so altitude, where information radioed to them from the ground allows them to point their rods at the U.S. lasers and detonate. The Soviets have had poor

success at building an x-ray laser; theirs are 100 times less bright than the ideal x-ray laser described in Section 3.3. Nonetheless, by pointing all its lasing rods at the same target, a Soviet x-ray laser can destroy a U.S. laser battle station at 10 Mm range. The U.S. chemical lasers attack the Soviet x-ray lasers as they ascend, but at this range long dwell times are required to destroy the Soviet lasers. By launching enough x-ray lasers simultaneously, the Soviets succeed in getting some to 100 km altitude, where they can shoot out through the thin atmosphere, before the U.S. lasers can destroy them. In this way, the Soviets "punch a hole" in the U.S. defensive constellation. (At a minimum, the Soviet ASAT attack consumes precious laser fuel aboard the U.S. battle stations.)

Just to make sure, the Soviets also deploy some powerful ground-based excimer or free electron lasers to destroy the U.S. battle stations as they orbit helplessly through space.

5.2 FAST-BURN BOOSTERS

Shortening the boost time and lowering the burnout altitude is easily accomplished at little sacrifice in useable ICBM payload (see Section 2). Shorter boost time increases the number of lasers needed for space-based laser or ground-based laser systems to handle simultaneously launched boosters. Short burn time makes rocket-propelled kinetic energy systems impractical, since the radius of action of each satellite becomes too small. Short burn time, together with low burnout altitude, would severely compromise the effectiveness of x-ray lasers popped up even from subs near Soviet shores. Low burnout altitude nullifies the neutral particle beam, which cannot penetrate very far into the atmosphere.

Fast-burn boosters would therefore be a potent, even decisive, countermeasure against almost all concepts for boost-phase intercept.

5.3 COUNTER C³I TACTICS

Countermeasures to the crucial functions of target sensing and command and control are a relatively unexplored, but probably key, problem area for directed energy BMD. In the case of terminal and midcourse defenses, the issues of decoy discrimination, confusion caused by chaff and aerosols, radar blackout and infrared redout, radar jamming, and traffic handling have always been and remain central limitations. It is likely that analogues will be found for boost-phase systems. Devising countermeasures requires a degree of specificity about the nature of the defense system which cannot be provided in the present conceptual stage. There follow a few examples of C³I countermeasures, by no means an exhaustive list.

A first point to note is that sensors are likely to be the most vulnerable part of a defensive satellite. A laser shined into an optical sensor can daze or injure the focal plane elements, though viewing in frequency bands absorbed by the atmosphere offers protection from ground-based lasers. Mirrors would be very susceptible to damage from a Soviet x-ray laser. A Soviet neutral particle beam could disrupt electronic circuits on U.S. satellites. Radiation pumped into the van Allen belts by nuclear bursts would affect sensors and electronics.

A single nuclear burst causes the upper atmosphere to glow brightly over areas 100 km in radius for over a minute. Calculated radiances[2] are large enough to cause background problems for MWIR tracking sensors.

[2] S. D. Drell and M. A. Ruderman, *Infrared Physics*, Vol. 1, p. 189 (1962).

Some directed-energy weapons produce spots only meters wide at the target, requiring target sensing to commensurate precision via laser radar (see Section 4.1). Laser radars sense laser light reflected from the target. A small corner reflector affixed to the target would produce a bright glint of reflected light, as would other corner reflectors launched on sounding rockets, ejected from the target, or attached to the target by extendable booms. These proliferated corner reflectors might force the beam weapon to attack them all.

The homing sensor of a kinetic energy interceptor could be susceptible to spoofing, depending on its type.

Jamming satellite-to-satellite communications crosslinks is probably *not* an effective offensive tactic, since the links would have narrow beamwidths, requiring the jammer to locate itself directly between the two satellites; and wide bandwidths, requiring high jammer power.

5.4 SHIELDING

A degree of shielding from lethal effects is practical for all but the kinetic energy weapons but involves in each case different methods suited to the different physical principles at work. At the same time, large uncertainties plague all lethality estimates, and further testing and study will be needed before firm answers can be given for any of the systems. For thermal kill with a laser, a solid booster designed with some attention to a laser threat can probably easily be made to withstand 10 kJ/cm^2. Application of a gram or so of heatshield material on each square centimeter of booster skin can probably triple this hardness, and spinning the booster enhances hardness by another factor of three. Heatshield material is ablative, meaning that when heated it burns off, carrying away the heat in the combustion gases rather than conducting it through to the missile skin underneath. A factor of nine increase in hardness requires the defensive laser to dwell on the booster nine times as long or to approach within a third of the range. Though hardening a new booster from scratch is clearly easiest, there is no serious impediment to retrofitting ablative coatings on existing boosters. Applying a gram per square centimeter of ablative material to the entire body of the MX missile would require removing several RVs from the payload, since the coating would weigh well over 1,000 kg.

An interesting possibility, requiring further study, would involve injecting into the atmosphere or producing from atmospheric gases, either throughout the ICBM flyout corridors or in the vicinity of individual boosters, smoke or laser absorbing molecules. Likewise, dust clouds raised by groundburst weapons (delivered by cruise missiles or by ICBMs that "leak" through the defense) might cause serious propagation problems for the ground-based laser scheme.

Hardening to an x-ray laser involves quite different physical principles. Recall that the x-ray energy is deposited in a paper-thin layer of the booster skin. The superheated layer explodes, applying an impulsive shock to the booster. Obviously a paper-thin shield between the booster and the laser will stop x-rays from reaching the booster wall. But the problem then becomes the debris from the exploding shield. One can easily show by calculation that the debris applies virtually the same impulse to the wall of the booster as would result from direct impinging of the x-rays! A number of schemes can be devised to divert the debris from striking the booster, but these require more study to implement in practice. One factor acting in favor of the shield designer is that the booster is not vulnerable to x-ray attack until it leaves the atmosphere. The lightweight shields therefore do not have to be designed to suffer large drag forces.

The neutral particle beam presents a third distinct type of hardening problem. The energetic beam particles penetrate into the target, and several centimeters of lead would be required to stop them. Since the beam cannot penetrate very far into the atmosphere, only the upper booster

stages need be hardened. But if the third stage, say, of the MX were covered with a few grams per square centimeters of lead, the shielding alone would weigh as much as several RVs. On the other hand, if the neutral particle beam is only designed to disrupt or damage sensitive electronics, but is not powerful enough to do damage to other parts of the missile, only the sensitive components need be shielded. The weight penalty then becomes small.

It is possible that the offense can extend the protection of the upper atmosphere against the neutral particle beam by exploding a few nuclear weapons at moderate altitudes before the beam can reach them. The detonations heat the air, which rises, effectively elevating the altitude at which the neutral beam is stripped of its remaining electron and bent in the geomagnetic field. This phenomenon is called atmospheric heave. It is as yet unresolved whether atmospheric heave will loft enough air to make a difference to the engagement altitude of the x-ray laser.

5.5 DECOYS

There is no way for a decoy booster to mimic closely the hot exhaust plume of an ICBM booster except by burning a similar rocket stage. One can add chemicals to the propellants to brighten a small booster's plume and dim the ICBM's, but as a first approximation a faithful decoy must be another booster.

Decoy tactics are therefore not as attractive for boost-phase intercept systems that use plume sensing as they are for midcourse and reentry defenses, where large numbers of cheap, lightweight decoys can be carried with negligible offload of RVs. Still, the usefulness of a decoy depends not on how expensive the decoy is, but on how the cost of the decoy compares to the cost of the defense that intercepts it. Booster decoys would not be nearly as expensive as true ICBMs, since they carry no warheads or precision guidance system, they need not be highly reliable, and they might not need to be based in underground silos but can be deployed above ground next to the ICBM silos.

Some of the boost phase intercept systems must grow in the number of their deployed battle stations in direct proportion to the number of Soviet boosters. Deploying one decoy (with a dummy payload) next to each of the 1,400 Soviet ICBM silos might cause the United States to have to double the number of battle stations overhead (and thus worldwide, multiplying by the absentee ratio) to handle the extra traffic. If the defensive battle stations were at all expensive, this would be an unpleasant prospect for the United States.

Many directed energy schemes would not rely on plume sensing alone (see Section 4.1). Decoy tactics against laser radars (including corner reflectors; see Section 5.3) might be much easier for the offense to implement than mimicking the booster plume.

5.6 SALVO RATE

The worst-case attack for all the boost-phase intercept schemes is massive, simultaneous launch of all Soviet ICBMs. The defensive satellites over the Soviet silo fields at the moment of launch then have to handle the entire attack.

A more leisurely salvo rate would allow laser and particle beam defenses that have to dwell on their targets more time to handle more targets. Slow attack also allows pop-up defenses to climb to intercept position. An attack drawn out 10

minutes or longer allows fresh defensive satellites to move along their orbits into position overhead, replacing depleted satellites. The orbital period of satellites in low earth orbit is about 90 minutes. If there are 8 to 10 satellites in each ring of the defensive constellation, satellites replace one another every 10 minutes or so.

An exception to this simultaneous-launch worst-case analysis is the x-ray laser, which delivers all its energy in an instant.

There would seem to be few military penalties for the Soviet Union to adopting plans to launch all their ICBMs in large attack within a few minutes. Indeed, if one of their objectives is to destroy U.S. ICBMs in their silos, rapid attack would be the best Soviet choice. Some, though not all, of the successful attacks that could be mounted on Closely Spaced Basing (Densepack) for MX involve very slow or intermittent salvo rates, however.

More importantly, in many circumstances the Soviets might wish to launch only a fraction of their ICBM force. A U.S. defense deployment too small to intercept all boosters in a massive attack would still be able to handle a small attack. A light defense might therefore establish a "threshold" of attack intensity below which Soviet boosters would face intercept. This prospect is discussed further in Section 9.

5.7 OFFENSIVE BUILDUP

The most straightforward way for the offense to compete with the defense is to grow in size. If for every new ICBM added to the Soviet arsenal, the U.S. defensive satellite constellation must be augmented at comparable or greater cost, the Soviets could challenge the United States to a spending race to their net advantage. On the other hand, if the defensive buildup is cheaper than the offensive buildup, the defense forces the offense either to accept limitations on its penetration or to resort to qualitative changes in its arsenal.

As an illustrative example of such a cost tradeoff, consider the hypothetical HF chemical laser system described in Section 3.1. Each laser in that system requires 1.7 seconds of dwell time to destroy a booster. During the 200 seconds of boost, each laser overhead can therefore destroy 120 boosters. But for each laser overhead, 32 are needed worldwide. Suppose now that the Soviets deploy, in one region of the U.S.S.R., 1,000 Midgetman missiles at a cost of 10 to 20 billion U.S. dollars (see Section 2). The U.S. defense now needs to be "beefed up" with addition of $(1{,}000) \times (32)/120 = 270$ laser battle stations. A tradeoff of more than one complex U.S. satellite, launched and maintained on orbit, for every 4 Soviet boosters (or decoy boosters) deployed on the ground would certainly appear to be a losing proposition for the United States. This is true even though the hypothetical HF laser system represents a very favorable outcome of laser technology.

Note that Soviet deployment of new ICBMs in one region of the Soviet Union, within coverage of only a single U.S. satellite, gives them the best leverage in the cost exchange.

5.8 NEW TARGETING PLANS

Truly efficient ICBM defenses would presumably force upon the superpowers a stricter attention to targeting priorities. With thousands of warheads in today's arsenals able to be literally lobbed into any target area unimpeded, the superpowers have less need to be discriminating or parsimonious in their nuclear targeting. Such a shift might have both desirable and undesirable

consequences. For example, the offense might decide that in view of the cost of countermeasures it could no longer afford to threaten the other side's ICBM silos. The warheads "freed up" from the countersilo mission might then be dedicated to heavier targeting of other aimpoints (perhaps cities) as a hedge against poor penetration. How the superpowers would greet these hypothetical defenses is not clear, but it is probably quite wrong to imagine future defenses acting against offensive forces targeted according to the war plans of today.

5.9 OTHER MEANS OF DELIVERING NUCLEAR WEAPONS

One additional Soviet response to an efficient defense against their ICBMs would be increased emphasis on submarine-launched ballistic missiles (SLBMs), bombers, cruise missiles, and whatever novel methods time and ingenuity might in the future devise for introducing nuclear weapons to the United States. As defenses forced up the cost-per-delivered-warhead of ICBM forces, these other methods would become relatively more attractive. Though they would sidestep the BMD, these delivery means have higher pre-launch survivability than ICBMs, and bombers and cruise missiles have longer times of flight. These attributes are usually seen as "stabilizing." Shifting the emphasis of the arms competition away from ICBMs is therefore sometimes viewed as adequate payoff for the BMD effort.

SLBMs would obviously be vulnerable to the same boost-phase weapons as ICBMs. The same worldwide coverage, reflected in the absentee ratio, that plagues the anti-ICBM cost exchange means that orbiting boost-phase defenses threaten SLBMs the world over. However, midcourse and terminal tiers of a layered defense would in general have much less capability against SLBMs, because of the latter's short time of flight, possibly depressed trajectory, and uncertain direction of attack. Thus SLBMs could conceivably enjoy greater penetration of a layered defense than ICBMs.

If one takes an optimistic view of emerging defensive technologies, or if one contemplates technological "breakthroughs," it is at least conceivable that such developments will spawn new ways of delivering or aiding the delivery of nuclear weapons as well as new ways of interdicting them.

Section 6
A WORD ON "OLD" BMD AND "NEW" BMD

No one knows whether directed-energy weapons can be built with the characteristics assigned to the hypothetical systems of Section 3. Even if such systems can be built, it is not clear that their performance will match, much less exceed, the performance of terminal and midcourse BMD systems in level of protection (attack price) and in cost relative to offsetting offensive improvements. The boost-phase BMD systems receiving so much attention today were a year ago at the periphery, to say the least, of technical discussion of missile defense. It is important not to lose sight of the status of traditional reentry and "advanced" (as they were called a year ago) "overlay" midcourse BMDs.

Naturally, the promise of the better-understood terminal and midcourse systems does not seem so grandiose, nor the flaws so clear-cut, as they do for the conceptual boost-phase defenses discussed in this Background Paper. Sounder technical assessments can be made of the "old" BMDs than of the "new" concepts. Rough concepts gloss over all the difficult design problems that inevitably limit achievable performance and turn up serious problems; nonetheless, identifying potentially unsolvable problems at this early stage of study does not mean they will remain insurmountable. BMD architectures incorporating boost-phase intercept are not known to be able to perform better, dollar-for-dollar, than BMD architectures incorporating only midcourse and reentry intercept. They are just not known to be worse. Terminal defense systems have been studied, designed, and tested for years, and it is generally agreed that such systems, acting alone, can enforce a modest attack price of between 2 and 8 RVs (perhaps equivalent to 20 to 80 percent of a booster) per defended aimpoint. Though their capabilities are modest, reentry and midcourse defenses suffice for modest defensive goals. There is no need to incur the technical risk of "new" boost-phase intercept schemes unless one aspires to levels of performance clearly beyond those possible with "old" concepts.

Many of the "new" concepts for boost-phase intercept are not new at all. They have been studied and discussed in one form or another for 20 years. Conversely, there are some new ideas for improving terminal and midcourse BMDs.[1] The spirit of technical optimism that accompanied the new emphasis on boost-phase intercept in the past year affected thinking about "old" BMD as well.

For terminal defense systems, the new features receiving attention are, first, non-nuclear warheads on interceptor missiles and, second, airplane-borne infrared sensors as supplements to ground-based radars. The principal benefit of non-nuclear intercept is that interceptors can be deployed nationwide without public concern about the safety of defensive nuclear warheads. Non-nuclear kill does not permit the defense to avoid all the disruptive effects of nuclear bursts, however, since the offense can still arrange for RVs to detonate when they sense interceptor impact ("salvage fuzing"). The miss-distance/weight relationship of the non-nuclear warhead requires the interceptor to approach more closely to the RV, and this in turn requires a homing seeker on the interceptor. Terminal homing obviously creates new opportunities for offensive countermeasures.

Airborne optical sensors obviously do not suffer radar blackout, but they can suffer the analogous problem of infrared redout. Decoy discrimination remains a problem, though it acquires some interesting new features. Details of these new aspects of terminal BMD are obviously classified. Though important, these aspects are fairly straightforward extensions of traditional techniques rather than revolutionary "breakthroughs."

New thought about midcourse defense focuses on alleviating the Achilles' heel of systems that use infrared sensing to support intercept in space: the ease with which the offense can accompany attacking RVs with clouds of decoys. One approach receiving attention is simply to cheapen the interceptor and shoot at everything, RVs and decoys alike. Another is to probe the attacking

[1] See Julian Davidson, "BMD: Star Wars in Perspective," *Aerospace America*, January 1984, p. 78.

objects with an active sensor, rather than relying on their thermal emissions, in the hope of discriminating RVs from decoys. Some of these "active discrimination" schemes are complex and expensive and might in turn be susceptible to offensive spoofing. A third aid to discrimination is the boost-phase defensive layer itself, which might constrain the number and type of penetration aids the offense could mount on each booster in addition to reducing the total number of objects approaching the midcourse tier. Fourth, extensive use of space-based sensors would allow the defense to observe penetration aids throughout their flight (including during deployment from the bus) rather than just as they approach the United States. It remains unclear whether these techniques will be worth the costs and new countermeasures they would bring to the defense.

Section 7
A HYPOTHETICAL SYSTEM ARCHITECTURE

Most analysts of boost-phase BMD assume that midcourse and terminal BMDs will augment the boost-phase layer. This section assembles a hypothetical layered defense system *in toto*. This system is *purely illustrative*, taking current BMD concepts at their face value and conveying a concrete image of the defensive architectures analysts apparently have in mind when they speak of nationwide defense. Obviously there are many choices for such a "strawman" system. The particular system described below was chosen for its illustrative value and not because it represents some "most plausible" alternative. It would be meaningless to suggest a "front runner" in the present state of study and technology development. Rather, the purpose of this example is to show how the layers interact and to indicate the overall scale of the deployments contemplated, without implying that anything remotely like it ever could or would be built.

A defense with several layers presents the offensive planner with some of the variety of problems that afflicts the BMD designer, who never knows in advance which attack tactic or countermeasure the offense will choose and must include responses to all of them in the system design. Layered defense forces the offense not only to develop responses to all the layers, but to develop responses that can be accomplished simultaneously. Thus, for example, the method chosen to avoid boost-phase intercept must not prevent deployment of lightweight midcourse decoys. The synergistic effect of the several layers obviously works strongly in the defense's favor.

Nonetheless, one must compare the performance of a three-tiered defense to the performance of a two-tiered defense of the same cost. Thus it should be no surprise if a $200 billion system with boost (and possibly even post-boost), midcourse, and terminal layers performs better than a $50 billion system with no boost phase layer. The correct questions are whether the additional $150 billion is worth the extra performance, and whether spending the $150 billion on more terminal and midcourse defense would in fact be a better investment.

Occasionally one sees a simplified leakage calculus applied to layered defense. The calculus assigns a "leakage" of, say, 25 percent (0.25) to the boost phase layer, 15 percent to the midcourse layer, and 10 percent to the reentry layer, deducing an "overall leakage" of 0.4 percent on the basis of the equation $(0.25) \times (0.15) \times (0.10) = 0.004$. Though the term leakage can be defined so that this calculus holds, the result actually bears little relation to the number of targets preserved by the defense. For one thing, a given defensive layer does not have an associated leakage *fraction* independent of attack size: the leakage fraction for each layer usually increases with attack size, most obviously (but not only) when the defensive arsenal becomes saturated. Second, the performance levels of the individual layers are not independent. For example, if the midcourse layer's interceptor arsenal is sized to handle only 25 percent of the attack, and the boost-phase layer works poorly and in fact allows 50 percent of the attack through, the midcourse layer obviously cannot display the same fractional efficiency against the attack of double the expected intensity. Conversely, improvements in one layer might improve performance of another: effective boost-phase or midcourse layers might force the offense to abandon the highly structured "laydowns" of RVs in space and time that limit a terminal layer's effectiveness. Third, the raw number or fraction of leaking RVs does not indicate the number or fraction of targets destroyed because of the tactics of preferential offense and defense. For these reasons, the leakage calculus is not a helpful way to encapsulate layered defense performance.

7.1 SYSTEM DESCRIPTION

The system design described below takes literally the goal of comprehensive nationwide defense. It seeks the capability (at least on paper) to engage all attacking Soviet missiles, whether targeted at cities, U.S. silos, or other military installations. Clearly the precise numbers and kinds of components in this description can be adjusted to suit any set of assumptions. The point of this description is merely to convey the flavor of these massive architectures. Most assumptions are favorable to the defense.

Suppose that at some time in the future the Soviet ICBM arsenal still consists of 1,400 boosters, as it does today. For simplicity, suppose further that each booster is an MX-sized solid propellant missile carrying 10 RVs and that all silos are located in one large region of the U.S.S.R. The boosters are not specially shielded against lasers, but some care in their design has given them an effective hardness of 10 kJ/cm², and they are further spun during ascent. Each booster carries a small number of decoys, but their small number is offset by the decoys' high fidelity. Each RV is accompanied by 9 lightweight infrared replicas and 1 high altitude reentry decoy. (This is a very modest penetration aid loading. One can assume larger numbers with perhaps poorer fidelity, chaff and aerosols, etc.)

The hypothetical U.S. defense system comprises both HF chemical laser battle stations and x-ray laser battle stations for boost-phase intercept, land-based midcourse interceptors carrying LWIR homing vehicles (the so-called "Overlay"), and land-based high-endoatmospheric homing interceptors with non-nuclear warheads for reentry intercept.

Table 7.1.—Hypothetical Future U.S. Defense Designed for Nationwide Protection Against Hypothetical Future Soviet Offense

U.S. Defense	Soviet Offense
5 warning satellites	1,400 MX-like ICBMs deployed in one region
160 HF laser satellites	10 RVs per ICBM
160 laser radars	9 midcourse decoys per RV
900 x-ray laser satellites	1 reentry decoy per RV
900 MWIR trackers	
28,000 midcourse intercept vehicles and boosters	
20 LWIR satellites	
75 radars	
140,000 terminal non-nuclear interceptors	
25 aircraft with LWIR sensors	

SOURCE: Author.

The HF chemical laser system resembles that described in Section 3.1, except that it has only five 20 MW lasers at each position in the 32-position constellation, for a worldwide total of 160. At a range of 2 Mm, a laser must dwell on each spinning booster for 5 seconds, so each laser at this range can handle 30 simultaneously launched boosters if defense begins 30 sec into the 180 sec boost phase of an MX-like booster. The five lasers overhead the Soviet silos at any one time can therefore only handle 150 of the 1,400 Soviet ICBMs. For small Soviet attacks, however, this non-nuclear boost-phase layer suffices.

For a large-scale Soviet attack, the United States deploys in addition a nuclear boost-phase system of x-ray lasers. A "perfect" laser with characteristics such as those derived in Section 3.3 can intercept ideally about 50 boosters at 4 Mm range. Therefore 28 lasers need to be in position over the Soviet silos at any time to handle a massive launch, giving a worldwide total of 900 (absentee ratio 32).

Warning for the boost-phase system is provided by MWIR warning satellites in synchronous or supersynchronous orbits. Also, each of the 160 HF laser battle stations has an MWIR telescope with 4 m mirror and an ultraviolet or visible ladar with 2 m mirror for pointing. Each x-ray laser is accompanied by an MWIR telescope tracker with 1 m mirror.

The 1,400 Soviet boosters carry 14,000 RVs, 126,000 midcourse decoys, and 14,000 reentry decoys. The United States assumes that only 10 percent of the boosters will survive the boost phase defense, so the midcourse tier needs to face 1,400 RVs and 12,600 midcourse decoys. The midcourse interceptors are given extremely long range, so only two bases are needed to cover the entire United States. However, each base must be prepared to absorb the entire attack, since the Soviets could target one half of the country more heavily than the other. There-

fore the United States needs 14,000 midcourse interceptors at each base, for a total of 28,000 interceptors. A constellation of 20 satellites with large LWIR sensors provide long-range acquisition and target assignment to these interceptors.

The United States next estimates that 90 percent of the RVs that enter the midcourse layer will be successfully intercepted. The terminal defense must handle 140 RVs plus 140 reentry decoys.[1] The reentry decoys are, by assumption, completely faithful in mimicking the signatures of RVs as seen by ground-based radars and aircraft-borne infrared sensors during early reentry—large decoy numbers have been sacrificed for this high fidelity. If the U.S. defense takes literally its charge of nationwide defense, it must be prepared to make 280 intercepts anywhere in the country.

[1]The number of reentry decoys the terminal system must face actually depends on whether the decoys fool the midcourse as well as the terminal system's sensors and on whether the terminal and midcourse layers cooperate in discrimination. Suppose first that the reentry decoys look like RVs (and therefore also like midcourse decoys) to the midcourse layer's sensor. Then the midcourse layer will intercept 90 percent of them (more midcourse interceptors must be bought to do this). If, on the other hand, the midcourse layer correctly identifies the reentry decoys as non-lethal objects, it might (a) not intercept them, requiring the terminal layer to plan to face 140 RVs plus 1400 reentry decoys, increasing enormously the required arsenal of terminal interceptors; (b) intercept them, in which case a reentry decoy is a perfect midcourse decoy, making possible a new threat—large numbers of midcourse decoys that look like reentry decoys rather than RVs; (c) radio the information, object-by-object, to the terminal defense fields.

Each terminal defense site consists of a phased-array radar and a number of high altitude non-nuclear interceptors. Additional target acquisition support is provided by a fleet of aircraft patrolling the U.S. periphery, carrying LWIR sensors. Each radar has a radius of action of over 200 km, so 75 or so cover the entire United States. However, an interceptor only covers an area about 50 km in radius. Since the area of the United States is about 8 million square km, over 1,000 interceptor sites would be needed for nationwide coverage. Should the defense have to reckon with intensive Soviet attack on some regions and no attack on others? Clearly, yes. But equipping each interceptor site to handle all 280 objects passing through the first two layers would require buying 280,000 interceptors! The defense would need to buy this many interceptors if it wanted to claim the literal capability to engage *all* Soviet RVs, *no matter* where they landed. Suppose, then, that the United States hopes for a more evenly distributed Soviet attack and deploys just half of the arsenal needed for complete coverage—140 interceptors per region. One radar might not suffice to handle all the RV traffic in its sector if the Soviets attack some sectors preferentially, but the United States nonetheless buys just 75 radars. Five aircraft on patrol at all times requires a backup fleet totalling perhaps 25.

Table 7.1 summarizes the offensive and defensive deployments.

7.2 ASSESSMENT

It is obviously not possible to assess the performance of a system, such as the hypothetical layered defense described above, whose components are not (and in many cases cannot be) designed today, much less assembled in an overall architecture. It is nonetheless worth sketching, in the illustrative spirit of this section, the issues that would require analysis if anything resembling Table 7.1 were ever proposed for deployment.

The first issue concerns the cost of the improvements to the system needed to offset growth in the Soviet ICBM arsenal—that is, the cost exchange ratio. The number of defensive weapons is proportional to the number of Soviet ICBMs. If the Soviets were to double the size of their ICBM arsenal, the United States would need to double the number of its x-ray lasers and interceptor missiles. (The number of sensors would generally have to increase also, though perhaps not in proportion to the Soviet buildup. The number of HF lasers could remain the same if the United States continued to intend to use this non-nuclear boost-phase layer to engage only Soviet attacks of 150 boosters or less.) Comparison of the two columns of Table 7.1 indicates that an arms race of Soviet offense and U.S. defense seems certain to favor the Soviet side greatly.

A second issue concerns the huge inventories of midcourse and reentry interceptors needed for nationwide defense. The arsenal of reentry interceptors shown in Table 7.1 is in fact only half the size needed for literally complete nationwide coverage, as remarked above. The cause of these large interceptor inventories—besides the obvious presence of decoys—is twofold: first, the low leakage sought by the defense precludes preferential defense, the tactic that makes silo defense so much more economical; and second, the limited coverage of each interceptor battery makes preferential *offense* possible for the attacker. The goal of nationwide low-leakage defense therefore forces the BMD system to forfeit the two sources of leverage that have historically impelled BMD towards the technically modest mission of defending compact silo deployments to relatively low survival levels.

Soviet countermeasures—besides straightforward buildup of ICBMs—is a third issue. The particular boost-phase layers described above are susceptible in varying degrees to all of the countermeasures described in Section 5, and the midcourse and reentry layers to their respective sets of countermeasures.

Defensive coverage against submarine-launched ballistic missiles (SLBMs) is a fourth issue. The boost-phase layers can intercept SLBMs launched from all points on the globe. Though the average range from laser satellite to booster is larger at equatorial and polar latitudes than at the mid-latitudes where Soviet ICBMs are located, the number of SLBMs that could be launched in a short time from each ocean area is also much smaller than the huge number of ICBMs that could lift off simultaneously from the U.S.S.R. Even the chemical laser deployment alone might suffice for boost-phase coverage of SLBMs. The midcourse and reentry layers, however, would in general not perform as well against SLBMs as against ICBMs. SLBM trajectories present bad viewing angles to the midcourse layer's LWIR sensors, and the short timeline limits interceptor coverage. The reentry layer would need to be augmented with more airborne sensors and more radars (or radar faces) to cover attack from the ocean. In general, then, a layered system optimized for ICBM defense could not necessarily handle SLBMs as well.

Section 8
DEFENSIVE GOALS I: THE PERFECT DEFENSE

No assessment of whether a defensive system "works" or not is meaningful without a clear and direct statement of the goal of the deployment. Though there has been much discussion of the feasibility of boost-phase BMD, proponents and skeptics alike frequently leave unstated the standards against which they are judging the technical prospects. A "successful" BMD deployment could be defined as anything from a truly impenetrable shield, to a silo defense that merely costs less to build than it costs the Soviets to overcome, to a tangled deployment that just "creates uncertainty" for the attacker.

The most ambitious conceivable goal for BMD would be to take at literal face value the words of President Reagan in his so-called "Star Wars" speech of March 23, 1983, when he called for development of a defense capable of making nuclear weapons "impotent and obsolete."[1] It is not clear that the President intended his words to be taken literally, nor that the Administration or anyone else is suggesting the United States seek a truly perfect or near-perfect defense.[2] Nonetheless, so much writing and debate focuses on this prospect, and its importance is so great, that it is taken up in this section. Section 9 treats the many other possible goals for less-than-perfect defenses.

There is some confusion in the literature about the use of the term "mutual assured destruction" (MAD) in connection with the notion of perfect defense. In common strategic parlance, MAD refers to the *technological circumstance* of mutual vulnerability to catastrophic damage from nuclear weapons, not to a *chosen policy* to promote such vulnerability. There is a strategic school of thought that advocates a policy usually called "minimum deterrence," maintaining that the capability for assured destruction of Soviet society is the *only* requirement of U.S. strategic forces. However, many experts believe that effective deterrence and other national security objectives require nuclear forces capable of many other tasks than assured destruction. This section addresses itself to the question of whether MAD is an avoidable technological circumstance, *not* to whether minimum deterrence is a prudent strategic policy.

A sensible start at judging the prospect for near-perfect defense must involve two steps: first, an exact statement of what perfect defense means in the context of attack on society with nuclear weapons; second, some way of gauging the likelihood of success when the technological future cannot be accurately predicted.

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[1] *Weekly Compilation of Presidential Documents*, Vol 19, No 12, March 28, 1983, pp 447-448 The text of the relevant part of the speech is reprinted as Appendix A

[2] Defense Secretary Caspar Weinberger appeared to confirm a literal interpretation in a March 27 interview on NBC's *Meet the Press*, when he said (as reported in the *Baltimore Sun*, March 28, 1983, p 1)

> The defensive systems the President is talking about are not designed to be partial What we want to try to get is a system which will develop a defense [sic] that is thoroughly reliable and total I don't see any reason why that can't be done

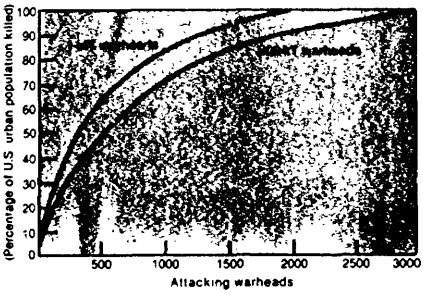
Later, the Defense Department stated that the purpose of the President's initiative was not to save lives, but to deter war Responding to the "Congressional Findings" section of the proposed "People Protection Act" (H R 3073, 98th Congress, 1st session) which stated, "The President has called for changes in United States strategic policy that seek to save lives in time of war," Defense Department General Counsel William H Taft IV wrote

> It is clear that portions of the Congressional findings section [of H R 3073] vary from the purpose of the President's initiative First and most importantly the purpose of the President's initiative is to strengthen our ability to deter war by as the President has said rendering [ballistic missiles] impotent and obsolete In short the purpose of the Administration's policy is to reduce the likelihood of war The finding [of H R 3073] that the purpose is to "save lives in time of war" departs from our goal of deterring war

Dr Charles Townes, a frequent adviser to Secretary of Defense Weinberger and leader of two DOD task forces studying basing modes for the MX missile said that a perfect defense proposal is quite impractical There is no technical solution to safeguarding mankind from nuclear explosives (*New York Times*, April 11 1983, p 14)

8.1 NUCLEAR ATTACK ON SOCIETY

Figure 8.1.—The Effect of Attack Size on the Extent of Prompt Fatalities in U.S. Urban Areas



Note: Aimpoints chosen to maximize prompt human fatalities. U.S. urban population is estimated to be 131 million, as in the 1970 census.

SOURCE: Arms Control and Disarmament Agency, *U.S. Urban Population Vulnerability* (ACDA, 1979), quoted in Arthur M. Katz, *Life After Nuclear War: The Economic and Social Impacts of Nuclear Attacks on the U.S.* (Ballinger, 1982). Adapted from Ashton Carter and David N. Schwartz, eds., *Ballistic Missile Defense* (The Brookings Institution, 1984), p. 188.

Suppose one wants to take literally the goal of removing from the hands of the Soviet Union the ability to do socially mortal damage to the United States with nuclear weapons, so that the Soviet Union no longer possesses the elemental capability of assured destruction.) What does this mean?

Figure 8.1 shows how the percent of the U.S. urban population (about 130 million people in the 1970 census) killed promptly increases with the number of Soviet warheads detonating over U.S. cities. No such curve of the effects of nuclear attacks on cities should be taken as anything but suggestive: uncertainties are very great in such estimates, and no attempt has been made to reflect long-term and indirect effects of the detonations.[3] The curve also accounts only for fatalities, not for the many additional people injured. If one wishes to account for the possibility of civil defense evacuation, then the curve should be taken to represent not the number of people killed, but the number of people whose homes, businesses, historic monuments, schools, and places of worship have been destroyed.

No one supposes that the Soviet Union actually chooses aimpoints for its nuclear weapons with the goal of maximizing human fatalities, as has been done in preparing Figure 8.1. If the United States possessed a defense capable of intercepting all but a few of the 8,000 to 10,000 Soviet nuclear warheads, however, the Soviet Union might retarget its forces to wreak the most destruction possible with its few penetrating warheads. At any rate, any defense promising U.S. society genuine immunity from nuclear attack must reckon with Soviet determination to keep its arsenal from being "rendered impotent," and therefore with targeting plans contrived to do the most damage to the fabric of U.S. society.

Where on the curve of Figure 8.1—after how many detonations—does one locate the boundaries of "assured destruction," "assured survival," "impotent and obsolete," and similar phrases? Clearly there is no analytical prescription for these boundaries: they are the subject of a broader human judgment. 500 half-megaton warheads kill half the urban population, injure most of the rest, and totally destroy all American cities and large towns. Just 5 megatons, about one two-thousandth of the Soviet arsenal, detonated over the 10 largest U.S. cities could kill several million people and wound over 10 million more.

For the sake of discussion, we shall use 100 megatons—about 1 percent of the Soviet Union's arsenal and 1.5 percent of its ICBM force—as the level of penetration for which a defense would

[3]For discussion of some of the effects of nuclear weapons on population and cities, see U.S. Arms Control and Disarmament Agency, *An Analysis of Civil Defense in Nuclear War* (ACDA, 1978); OTA, *The Effects of Nuclear War* (GPO, 1979); ACDA, *The Effects of Nuclear War* (ACDA, 1979); "Economic and Social Consequences of Nuclear Attacks on the United States," prepared for the Joint Committee on Defense Production, 96 Cong. 1 sess., 1979; J. Carson Mark, "Global Consequences of Nuclear Weaponry," *Annual Review of Nuclear Science*, Vol. 26 (1976), pp. 51-87; National Research Council, *Long-Term Worldwide Effects of Multiple Nuclear-Weapons Detonations* (National Academy of Sciences, 1975).

be judged "near-perfect." This definition is obviously very generous to the notion of perfect defense, since most people would presumably not regard 100 megatons of explosive force as "impotent and obsolete." Still, it is a definite reference for assessment.

8.2 THE PROSPECTS FOR A PERFECT DEFENSE

There is not and cannot be any "proof" that unknown future technologies will not provide near-perfect defensive protection of U.S. society against Soviet ICBMs. The question that needs to be answered is whether the prospects for near-perfect defense are so remote that such a notion has no place in reasonable public expectations or national policy. It is, after all, not provable that by the next century the United States and U.S.S.R. will not have patched up their political differences and have no need to target one another with nuclear weapons. The issue of the perfect defense is unavoidably one of technical judgment rather than of airtight proof.

Four misapprehensions seem common among non-technical people addressing the prospects for perfect defense.

The first misapprehension is to equate successful technology development of individual *devices*—lasers, power sources, mirrors, aiming and pointing mechanisms—with achievement of an efficient and robust defensive *system*. Millionfold increase in the brightness of some directed-energy device is a necessary, but is far from a sufficient, condition for successful defense. In the early 1960's, intercept of RVs with nuclear-tipped interceptor missiles was demonstrated—"a bullet could hit a bullet"—but 20 years later systems incorporating this "kill mechanism" are still considered relatively inefficient. In general, skeptics about the future of space-based directed-energy BMD do not confine their doubts to, or even emphasize, unforeseen problems in developing the individual components.

A second misappprehension arises in attempts to equate BMD development to past technological achievements, such as the Manhattan project's atomic bomb or the Apollo moon landings.[4] The technically minded will recognize a vital difference between working around the constraints imposed by nature, which are predictable and unchanging, and competing with a hostile intelligence bent on sabotaging the enterprise. A dynamic opponent makes of BMD, first, a more difficult design problem, since the offense constructs the worst possible barriers to successful defense; and second, not one problem but many problems that need to be sidestepped simultaneously in the design, since the designer cannot be certain which tactics the offense will use.

A third misapprehension concerns the prospect for a "technological breakthrough" that would dispel all difficulties. Such breakthroughs are not impossible, but their mere possibility does not help in judging the prospects for the perfect defense. For one thing, an isolated technological breakthrough creating a new defensive component would not necessarily alleviate the system issues—vulnerability, dependability, susceptibility to countermeasures, cost—that determine overall effectiveness. Second, one can just as easily imagine offensive "breakthroughs," sometimes involving the same technologies. Thus the x-ray laser, if it matures, might turn out to have been

[4]Defense Secretary Caspar Weinberger has written (*Air Force Magazine*, Nov. 1983).

> The nay-sayers have already proclaimed that we will never have such technology, or that we should never try to acquire it. Their arguments are hardly new . . . . In 1945 President Truman's Chief of Staff, Adm. William Leahy, said of the atomic bomb "That's the biggest fool thing we've ever done. The bomb will never go off, and I speak as an expert in explosives." In 1946 Dr. Vannevar Bush, Director of the Office of Scientific Research and Development said of intercontinental ballistic missiles, "I say technically I don't think anybody in the world knows how to do such a thing, and I feel confident it will not be done for a long time to come." These critics were proved wrong, what is more, they were proved wrong quickly.

better termed a breakthrough in strategic offense than a breakthrough in strategic defense.

A fourth misapprehension concerns the confidence with which predictions could be made about the performance of a complex system once in place. The "performance" of a system, as quoted in analyses, is the most likely outcome of an engagement of offense versus defense. Other outcomes, though less likely, might still be possible. Computing the relative likelihoods of *all* possible outcomes would be difficult even if one could quantify all technical uncertainties and statistical variances. Still, there would remain a residue of uncertainty about the performance of a system that had never been tested once in realistic wartime conditions, much less in a statistically significant ensemble of all-out nuclear wars. The defense would also have no chance to learn and adapt. In World War II, by contrast, air defense crews learned in raid after raid to inflict losses of several percent in attacking bombers. The only reason these modest losses assumed strategic significance was that they accumulated over many raids. Of course, the same uncertainties plague the offense as plague the defense. In general, the offense would tend to overestimate the defense's capability. This natural tendency toward "offense conservatism" is probably vitally important to the psychological and deterrent value of BMD as it is applied to less-than-perfect goals. For the perfect defense goal (as defined above), however, it would seem that the uncertainty weighs heaviest on the defense. To the reckless, non-conservative defense, a wrong estimate of defense performance spells the difference between safety and socially mortal damage (or between deterrence and war). The reckless offense, on the other hand, is presumed desperate enough to try to inflict such damage on its enemy and willing to accept the consequences: it stands to lose little if its estimates are wrong and the defense *does* work perfectly after all.

With these misapprehensions out of the way, and recognizing clearly that there can be no question of "proof," it would seem that four major factors conspire to make extremely remote the prospect that directed-energy BMD (in concert with other layers if necessary) will succeed in reducing the vulnerability of U.S. population and society to the neighborhood of 100 megatons or less.

1. **Near-perfect defense of society is much harder and more expensive than partial defense of military targets.** That is, the marginal cost exchange is much higher for near-perfect defense than for partial defense (see also Fig. 5.2). There are two reasons behind this well-known statement.

The first reason is illustrated schematically in Figure 8.2. In going from partial silo defense to perfect city defense, the BMD loses the leverage of preferential defense. Additionally, the offense gains the leverage of preferential offense against the terminal and midcourse layers with their limited geographic coverage, although *not* against the boost-phase layer. In Figure 8.2(a), the defense aims to save only 10 percent of the ICBM force, or one silo. Assuming perfect interceptors and adopting the tactic of adaptive preferential defense (using all its interceptors to save just one silo chosen randomly from the ten at the moment of attack), the defense concludes it needs to prepare to make one only intercept to counter the offense's 10 RVs. In Figure 8.2(b), the offense can focus all 10 of its RVs on any one of ten cities. The defense must prepare to make 10 intercepts for each city, buying a total of 100 interceptors, if it wants to try to save all the cities. If the Soviets double their RV arsenal, the United States must buy just one interceptor to satisfy the defense goal of Figure 8.2(a), but the United States must buy 100 interceptors to satisfy the defense goal of Figure 8.2(b). The cost exchange ratio is thus 100 times worse for the city defense, even though it uses the same technology as the silo defense.

The second reason why a near-perfect defensive goal shifts the cost burden in favor of the offense is that the offense can turn all its resources to improving or replacing just a portion of its ICBMs to sidestep the defense. The Soviet Union could therefore harden just 1 percent of its boosters, perhaps concealing exactly which ones were hardened. Moreover, it could deploy a few fast-burn boosters immune to x-ray lasers and neutral particle beams; build a few different ASAT de-

Figure 8.2

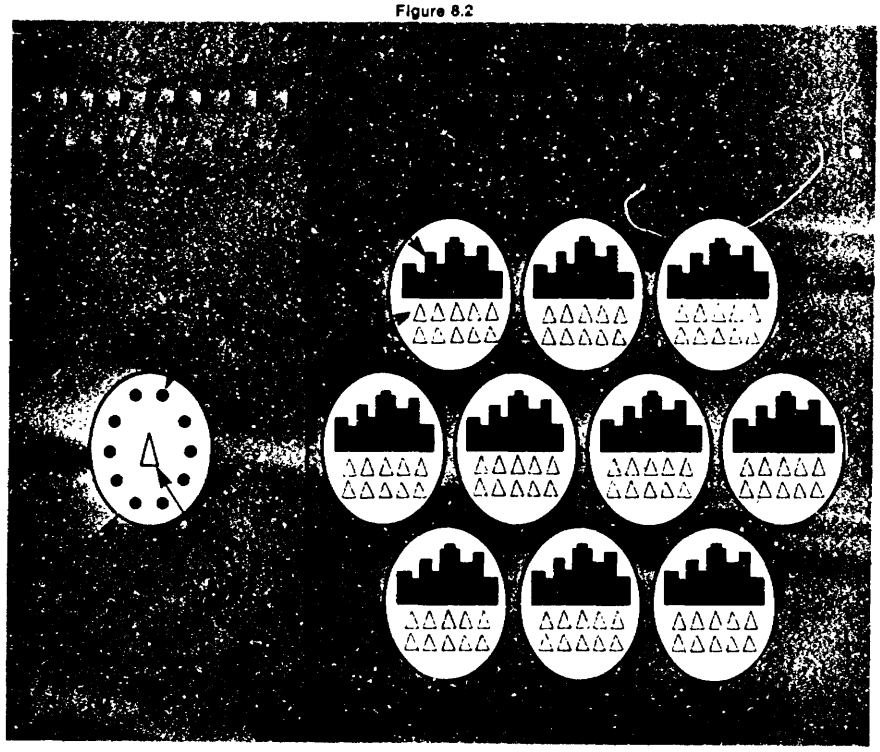


Figure 8.2 The cost to a U.S. reentry BMD to compete with increases in the size of the Soviet arsenal (the "marginal cost exchange") is much greater for near-perfect city defense (b) than for partial silo defense (a). In going from (a) to (b), the U.S. loses the leverage of preferential defense and the Soviet Union gains the leverage of preferential offense.

vices; and so on. More costly countermeasures are available to the offense if the countermeasures need only be implemented on a small scale rather than throughout the ICBM force. The offense can "experiment" with a number of different tactics with different portions of its force. The defense's costs also grow much larger if it must plan to face a *variety* of offensive countermeasures. In short, the defense must be able to stop all kinds of attack, but the offense only has to find one way to get through.

2. **For every defense concept proposed or imagined, including all of the so-called "Star Wars" concepts, a countermeasure has already been identified.** These countermeasures were enumerated in Section 5 and will not be repeated here. Three further generalizations about these countermeasures reinforce a poor prognosis for cost-effective near-perfect defense: 1) In general, the countermeasures could be implemented with today's technology, whereas the defense itself could not; 2) In general, the costs of the coun-

termeasures can be estimated and shown to be relatively low, whereas the costs of the defense are unknown but seem likely to be high; 3) In general, the future technologies presupposed as part of the defense concept would also be potent weapons for attacking the defense.

3. **The Soviet Union does not configure its nuclear missile forces today to maximize damage to U.S. society and population, but it could do so if faced with near-perfect U.S. defenses.** Targeting plans could focus exclusively on damaging cities. High missile accuracy would be unnecessary, lowering offense costs. Nuclear weapons could be designed to maximize harmful fallout. ICBM survivability measures—silos, racetracks, densepacks, etc.—would be unnecessary to a side striking first or possessing its own defense effective at saving many missiles (but not *all* cities); thus basing costs could be diverted to the city-kill goal. Presumably the Soviet Union would take these and any other measures necessary to prevent itself from being effectively disarmed by a U.S. defense, since otherwise it would be at its enemy's mercy.

4. **BMD by itself will not protect U.S. society from other methods of delivering nuclear weapons to U.S. soil or from other weapons of mass destruction.** Bombers and cruise missiles (and to a significant extent SLBMs and IRBMs) present very different defensive problems than ICBMs. Today the technical problems of air defense are no better resolved than the technical problems of BMD. Novel future offensive delivery vehicles can only be conjectured along with the future defense technologies discussed in this Paper. A desperate Soviet Union could introduce nuclear weapons into the United States on commercial airliners, ships, packing crates, diplomatic pouch, etc. Other methods of mass destruction or terrorism would be feasible for the U.S.S.R., including sabotage of dams or nuclear power plants, bacteriological attack, contaminating water, producting tidal waves with near-coastal underwater detonations, and so on.

Section 9

DEFENSIVE GOALS II: LESS-THAN-PERFECT DEFENSE

A host of less grandiose goals than perfect or near-perfect defense assume importance in certain theories about the workings of nuclear deterrence and the requirements of U.S. security. Thoughtful observers debate not just the feasibility of achieving these goals but the validity and importance of the goals as well. The urgency one attaches to these goals determines the costs, risks, and harmful side effects one is willing to incur to fulfill them. Assessing the wisdom of less-than-perfect defense thus involves a complex and subjective balancing of goals and risks, in which purely technical issues sometimes take a back seat. In discussion of perfect defense, by contrast, technical assessment is paramount. This section therefore calls up many issues of nuclear policy not subsumed under the title of this Background Paper, and no pretense is made here to complete treatment.[1]

Though various strategic goals for BMD can be distinguished in principle, in practice it might not be clear or agreed among all parties in the United States what the purpose of a proposed deployment actually was. Interpretations by the Soviet Union and other foreign nations of U.S. goals might be quite different yet.

[1]For a more complete treatment of the entire subject of BMD, see Ashton B. Carter and David N. Schwartz, ed., *Ballistic Missile Defense* (The Brookings Institution, 1984).

Those familiar with BMD design and assessment will recognize that stating a general *strategic* goal is not enough: the *technical* specifications are essential. For instance, it makes an enormous difference in silo defense whether the defense seeks to charge the offense a price of five RVs (or half a booster) or 10 RVs (one booster) per silo.

For goals requiring very modest performance, terminal and midcourse defenses might suffice. Since no one knows whether boost phase defenses, when better defined, will surpass or even equal traditional defenses in terms of leakage and cost exchange, there is no point in turning to exotic technologies to satisfy modest goals. Virtually all observers agree, on the other hand, that terminal and midcourse systems are unequal to the more demanding goals; for these goals one is forced to direct one's hopes to the promise of future technologies.

This section sketches various goals for less-than-perfect defenses and the strategic thinking that attaches importance to them. It then points out a number of side effects against which fulfillment of these goals needs to be balanced. This short section is no substitute for a comprehensive assessment of the pros and cons of BMD.

9.1 GOALS FOR LESS-THAN-PERFECT DEFENSE

1. **Strengthen deterrence by preventing preemptive destruction of retaliatory forces.** It is widely recognized that the Soviet Union will soon have, if it does not already, the combination of yields, numbers, and accuracy in its ICBM forces to destroy most U.S. Minuteman ICBMs in their silos. It is also widely agreed that vulnerable nuclear forces create unwanted temptations for both sides to strike first if war seems likely. The long and anguished search for survivable basing modes for the U.S. MX (Peacekeeper) ICBM has to date turned up no clear favorites when survivability is balanced against cost, technical risk, strategic effects, and environmental impacts.[2] BMD would substitute for or complement these other basing modes. By shooting down a fraction of the opponent's missiles, BMD would in effect "de-MIRV" ICBM forces.

Of course, turning to BMD to ease ICBM vulnerability is not without problems. One problem is the prospect of a compensating Soviet BMD.

[2]*MX Missile Basing*, Office of Technology Assessment, U.S. Congress, September 1981.

MX is presumably being bought and made survivable in the first place so that the U.S. can absorb a Soviet strike and retaliate with its ICBMs (in addition to its bombers and submarines) against Soviet targets. But modification or termination of the ABM Treaty to permit a U.S. defense would permit a Soviet defense as well. The surviving U.S. ICBMs guaranteed by the U.S. BMD might still not result in retaliatory damage to Soviet targets if these targets are defended by Soviet BMD. The U.S. BMD deployment, all bought and paid for, might therefore have been cancelled out by a Soviet counter-deployment.

Other elements of the U.S. retaliatory force comprise command and control links, bomber alert bases, and in-port submarines. Bomber bases, sub ports, and fixed command and control facilities are the worst type of target base for BMD to try to defend—a small number of high-value, soft, and interdependent targets. The important remaining category of mobile command and control facilities, on the other hand, does not easily lend itself to active defense with BMD.

2. **Strengthen deterrence by preventing the use of nuclear weapons as decisive military tools for high-confidence "limited" strikes on conventional forces.** This goal is associated with so-called "warfighting" strategies for nuclear weapons. According to analysts who hold this view, today's "offense dominated" world creates dangerous temptations to resort to nuclear weapons to accomplish militarily well-defined objectives. One can imagine warheads simply being lobbed unopposed into another country in any number or combination. Though surely the effects of these "limited" attacks on nearby communities would not be so well-defined, the effect on the opposing military machine might be truly dramatic, even decisive. This use of nuclear weapons in wartime is possible with today's unopposed offenses with considerable confidence and might therefore be tempting to the combatants. Such temptations threaten nuclear deterrence and should be eliminated. The goal of a comprehensive defense would be to make such limited attacks infeasible, or at least to complicate the offense's estimations of success to such a degree that it would not attempt an "experiment."[3] Analysts who favor this approach usually maintain that Soviet military doctrine inclines the Soviets towards a view of nuclear weapons as military tools to a far greater degree than is common in U.S. thinking.[4]

To take an explicit example (in this case of Soviet failure to deter the U.S.) of a "warfighting" scenario (chosen randomly from a great many possibilities), suppose NATO were at war with the Warsaw Pact, and the Soviets were resupplying their ground offensive through just 10 or so rail trunks from the Soviet Union through eastern Europe. Just 10 well-placed nuclear weapons (according to a hypothetical analyst considering this type of scenario) would cut off a large fraction of supplies coming to the front, slowing the Pact offensive and giving NATO vitally needed time to marshall its defenses. Wouldn't the United States be sorely tempted to use just a few ICBMs for this decisive intervention in the course of the war?

Analysts who recommend attention to warfighting scenarios and doctrines are surely aware of the profound difference between conventional and nuclear weapons, but they maintain that the threat of punishment through retaliation upon cities is not an effective deterrent in such scenarios. Wouldn't it be preferable if these scenarios were simply closed off by defensive technology?

Critics of this BMD goal object both to the warfighters' emphasis upon the risk of this type of scenario and to the assumption that defense would materially diminish that risk. In their view, myriad detailed chinks in the armor of deterrence can always be found, with or without defense, and worrying about them represents a loss of

[3] Presidential Science Adviser George A. Keyworth, II has stated (interview with *U.S. News and World Report*, April 11, 1983, p. 24):

> "The objective is to have a system that would convince an adversary that an offensive attack will not be successful. It has to be a very effective system, but it would not have to be perfect to convince a potential adversary that his attack would fail."

Dr. Robert Cooper, director of the Defense Advanced Research Projects Agency has also stated this view (*The New York Times*, Nov. 5, 1983, p. 32). "Even if only 50 percent of all incoming missiles were stopped, the Soviets could then have no confidence in the success of a first strike, and war would be more remote."

[4] *Ballistic Missile Defense*, op. cit., Chapter 5.

perspective on the basic difference between nuclear and conventional instruments of war. Besides, they say, suppose the effect of the Soviet BMD is to force the United States to attack each rail line with ten weapons instead of one to assure penetration: Is there truly a psychological divide between using 10 and 100 nuclear weapons, once the divide between 0 and 10 has been crossed? Third, would NATO not be adequately deterred by the prospect of Soviet retaliation with 10 of its nuclear weapons against 10 vital NATO targets? Last, suppose NATO used 10 cruise missiles, against which the BMD was powerless, instead of 10 ICBM RVs?

The persuasiveness of this second goal for less-than-perfect BMDs therefore depends on one's views of the roles and risks of nuclear weapons—views that are fundamental and deeply held. This goal is therefore one of the most controversial of all.

3. **Save lives.**[5] Another goal for BMD is purely humanitarian and seeks no military or strategic advantage. If the defense did not interfere too much with Soviet military targeting objectives (enough for the Soviets to try to overcome it), and assuming the Soviets have no explicit aim to inflict human casualties, the United States could expect some reduction in fatalities in a nuclear war even from a modest defense. This reduction would necessarily be limited, since Soviet military objectives include destruction of many targets collocated with population. BMD and civil defense measures would be mutually reinforcing.

Analogous discussion of civil defense has always revealed an inherent tension between the humanitarian objective of defense and a related strategic objective. The strategic objective seeks to reduce fatalities and damage in order to enhance U.S. "flexibility" in a crisis, to allow the United States to "coerce" the U.S.S.R. (or avoid coercion) from a position of reduced vulnerability, or to enhance U.S. ability to persist in its war effort despite receiving a Soviet nuclear strike. The supposed result of the BMD deployment is to allow the U.S. President, in dealing with the Soviet leadership in time of crisis, to be more willing or appear to be more willing to resort to nuclear war because the consequences to the United States are presumed smaller.

The coexistence of the humanitarian and strategic objectives for the analogous case of civil defense is apparent in the literature on civil defense. The Defense Department[6] has argued that the United States should have the same crisis relocation options as the U.S.S.R. for two reasons, one strategic and one humanitarian: 1) "to be able to respond in kind if the Soviet Union attempts to intimidate us in time of crisis by evacuating the population from its cities"; and 2) "to reduce fatalities if an attack on our cities appears imminent." Prominent scientists arguing for civil defense have also maintained that, "A nation's civil defense preparedness may determine the balance of power in some future nuclear crisis. . . . In our opinion, we must strive for an approximately equal casualty rate".[7] More recently, the High Frontier Study urging strengthened U.S. strategic defenses stated: "The protection of our citizens must be prime, but civil defense . . . would reduce the possibility that the United States could be coerced in a time of crisis".[8]

In practice, therefore, the humanitarian and strategic objectives are likely to be difficult to disentangle. Unlike the humanitarian objective, the strategic objective might stimulate a Soviet effort to put the same number of American lives at risk regardless of the defense. In this way, the Soviet Union could retain the strategic advantage that, by hypothesis, the BMD deprives them of. The issue then becomes the usual one of the cost-exchange ratio measuring the price to the Soviet Union of retaining its "advantage" relative to the price of the U.S. defense.

The Defense Department has stated that saving lives in time of war is not the purpose of President Reagan's BMD initiative.[9]

[5]This discussion borrows from the author's previous work in *Ballistic Missile Defense*, op. cit., Chapter 4.

[6]*Annual Defense Department Report, FY 1976*, p. II-24.

[7]Arthur A. Broyles and Eugene P. Wigner, "Civil Defense in Limited War," *Physics Today*, vol. 29 (April 1976), pp. 45-46.

[8]Daniel O. Graham, *The Non-Nuclear Defense of Cities: The High Frontier Space-Based Defense Against ICBM Attack* (Abt Books, 1983), p. 122.

[9]See footnote 8.2.

4. **Shape the course of the arms competition and arms control.**[10] One version of this goal sees the Soviet tendency to upgrade and proliferate existing ICBM forces as the principal impediment to arms control. By introducing BMD (or even discussing it), according to this view, the United States makes the Soviets unsure about the next step in the arms competition and thus undercuts the momentum of Soviet strategic programs, especially ICBM modernization. Though fast-burning Midgetman boosters might defeat boost-phase defenses, this argument goes, the slow-burning SS-18s and SS-19s will not. BMD might not be able to make all nuclear weapons impotent and obsolete, but it can make large Soviet ICBMs impotent and obsolete—something the U.S. has been trying to do for a decade. Perhaps efficient defenses will "force" the Soviets to emphasize submarines, bombers, and cruise missiles in their strategic arsenal to the same degree the United States does. (One problem with this line of argument is that by the time the defense is in place, present-generation Soviet ICBMs might already be replaced.)

Another line of argument holds that a major BMD initiative strengthens the U.S. negotiating position at START. An aggressive BMD program demonstrates U.S. technological prowess and hints at what the Soviets could face if this prowess were unleashed. It would seem that new BMD initiatives might not coexist easily with the reductions in offensive arsenals proposed by the United States in START, however. Since U.S. BMD is equivalent to attrition of the Soviet ICBM arsenal, any anxieties the Soviets feel at reducing the size of their missile inventories would, logically at least, be enhanced by a simultaneous U.S. BMD buildup. Politically, it would seem unlikely, though certainly not impossible, that a climate favorable to far-reaching offensive arms control would also foster an amicable dismantling of the ABM Treaty.

5. **Respond to Soviet BMD efforts.** Many analysts view with alarm Soviet strategic defense activities, including upgrading of the Moscow ABM, development of a transportable terminal BMD system, construction of a radar in apparent violation of the ABM Treaty, development of defenses against tactical ballistic missiles, incorporation of limited BMD capability in air defenses, and continued attention to other damage-limiting methods (civil defense, air defense, antisubmarine warfare, and countersilo ICBMs). A strong U.S. BMD research and development program might deter the Soviets from breaking out of the ABM Treaty and from continued encroachments on the Treaty's provisions. It is frequently noted that aggressive U.S. research into penetration aids and other methods for countering defenses might be an even more effective way to demonstrate to the Soviets that they would be ill-advised to overturn the ABM Treaty's "freeze" on missile defenses.

6. **Protect against accidental missile launches and attack from other nuclear powers.** These goals have been put forward several times in the past, most notably in the late 1960's when the Johnson Administration proposed the Sentinel ABM system to counter Chinese ICBMs, believed at that time to be fast-emerging. Neither goal figures prominently in today's discussion of BMD in the United States, though defense against Chinese, British, and French missiles could well loom larger in Soviet thinking. Emerging nuclear powers or terrorists would be unlikely to use ICBMs to deliver their small nuclear arsenals to the United States. BMD is therefore of little importance in staving off the threat to U.S. security posed by nuclear proliferation.

[10] Presidential science adviser George A. Keyworth, speech before the Washington chapter of the Armed Forces Communications and Electronics Association, as reported in *Defense Week* (Oct. 17, 1983):

> "Although the strategic defense program's goal would still be eventual deployment of a working system, we shouldn't overlook its potential beneficial impact on arms reduction as its progresses."

Richard DeLauer, Undersecretary of Defense for Research and Engineering, has said that an arms control agreement is needed to prevent the Soviets from overcoming a defensive system: "With unconstrained proliferation [of Soviet missiles], no defensive system will work." (Interview with *The New York Times*, May 18, 1983).

9.2 SIDE EFFECTS OF BMD DEPLOYMENT

The inevitable side effects of a major strategic initiative such as BMD might turn out to match, both in magnitude and in duration, the beneficial effects of satisfying the goal emphasized by the system's purveyors. The public and policymakers would therefore need to assess the net, long-term effect of adding BMD to the strategic equation, and not just the achievement of a certain discrete goal as if by surgical intervention. This section reviews the well-known list of BMD side effects. Many of these effects are detrimental to U.S. security and would need to be balanced against the benefits of fulfilling the modest goals of less-than-perfect defense. In making this assessment, it is impossible to ignore the many unknowns and uncertainties that make it impossible to compare today's world without BMD to a future world with BMD.

1. **First strike versus ragged retaliation.** It is frequently noted that BMD ends up being a better investment for the side that strikes first than for the side that retaliates. Weapon systems that create relative advantages to striking first in a crisis (rather than risking being struck while seeking a peaceful resolution) are defined to be "destabilizing." The side striking first uses its full arsenal in an organized penetration of the other side's defense; the retaliating side can only use its surviving arsenal in a possibly disorganized "ragged retaliation" against a forewarned and fully prepared defense.

Mitigating factors could in certain circumstances soften this classical statement of the destabilizing effect of BMD. First, truly effective defenses might prevent the first striker from destroying a substantial fraction of the other side's retaliatory forces. Second, with proper planning (involving post-attack retargeting and coordinated timing), the retaliating forces might still be able to mount a tailored, efficient strike. Third, there will seemingly always be a *relative* advantage to being the side that strikes first in a nuclear war, with BMD or without BMD; but this calculus of relative advantage is far from being the only factor in deterrence. Other stabilizing factors might be strengthened by BMD, offsetting this destabilizing factor. Thus BMD might also *discourage* temptations to strike first, by threatening to disrupt the attack.

2. **Soviet BMD.** A U.S. BMD deployment would seem very likely to stimulate a Soviet deployment. Even if the Soviets saw no compelling military rationale for following suit, political appearances could prove decisive. A Soviet BMD counter-deployment would obviously blunt U.S. offensive striking power, which the U.S. has been spending a great deal to build up. If the U.S. deployment sought to protect its ICBMs from preemptive destruction in their silos (Goal 1 above), the Soviet BMD might nonetheless nullify the U.S. ICBMs—this time in flight to their targets. Soviet BMD would also introduce a threat to U.S. SLBMs, which are today thought to be virtually immune to Soviet disruption and to be significantly advanced relative to their Soviet counterparts. If the U.S. deployment sought to prevent "limited" strikes by the Soviets Union (Goal 2), the Soviet BMD might in turn preclude a U.S. option to use nuclear weapons selectively and flexibly in support of its NATO allies—an option sometimes seen as central to NATO strategy. Clearly the actual effect of the Soviet BMD counterdeployment would depend upon its technical characteristics and the targets it defended.

3. **Demise of the ABM Treaty.** An arms control treaty obviously cannot serve as its own justification, and presumably virtually everyone would agree to the abandonment of the ABM Treaty the moment it ceased genuinely to serve the national security. In addition to its concrete provisions limiting BMD deployment, however, the ABM Treaty has unavoidably assumed a symbolic political meaning in the United States and, in different forms perhaps, in Europe and the U.S.S.R. The Treaty stands for a decade of arms control and attempts at superpower understanding about nuclear weapons. As a practical matter, it is impossible to overturn the Treaty's technical provisions without calling into question U.S. commitment to the whole fabric of the SALT/START process. This side effect would have to be weighed against the purely military and strategic

benefit (if there were, in fact, a net long-term benefit) of a U.S. BMD deployment.

4. **Allied and Chinese missile forces.** The nuclear missile forces of Britain, France and China are obviously a greater threat to the Soviet Union than to the U.S. Most analysts agree that the existence of these forces enhances U.S. security. But a major BMD initiative sparking widespread Soviet defense would in effect disarm our allies (to a degree depending on the nature of the Soviet deployment).

5. **Accompanying strategic programs.** A number of new weapon systems and strategic programs would be natural, though perhaps not necessary, accompaniments to BMD. On the offensive side, the U.S. would need to develop and deploy penetration aids against the Soviet BMD and improve its bomber and cruise missile forces to reflect added reliance on non-missile delivery vehicles. On the defensive side, the overall category of "strategic defense" comprises, in addition to BMD: nationwide air defenses against Soviet bombers and cruise missiles, defensive coverage against SLBMs, civil defense shelters and evacuation plans, and passive "hardening" of military installations and industrial facilities.

6. **Opportunity Costs.** The initial investment in BMD deployment, the inevitable follow-ons, and any accompanying strategic programs would make a substantial, permanent demand on the defense budget, competing with other nuclear forces and with conventional forces, not to mention with nonmilitary expenditures.

In a more fundamental sense, the transition from a world with a near-total ban on BMD to a world with BMD deployments is probably an irreversible change. Reimposing a defensive "freeze" after a period of unrestrained deployment, much less dismantling defenses and returning to zero, would involve all of the problems that attend upon arms control reductions at START today. Extra caution seems warranted where strategic actions cannot easily be reversed or recalled: the opportunity for a comprehensive ban on missile defense might not arise again.

7. **Bean counting.** Strategists, politicians, and diplomats place considerable emphasis on quantitative measures of the nuclear balance and on "proofs" that "parity" exists. Arms control negotiations also reduce themselves quickly to counting rules. It is unclear whether or how BMD should affect such "bean counting." For each U.S. battle station added to a defensive constellation, are the Soviets to be credited with fewer ICBMs, since the U.S. defense represents potential attrition of the Soviet force? How many Soviet interceptor missiles equals one U.S. laser? Whose estimate of the BMD's likely wartime performance—the defense's or the offense's—governs these counting rules? Experience indicates that these types of questions, however far-fetched and even preposterous they appear in prospect, in the end assume considerable perceived importance.

8. **Asymmetries.** The Soviet BMD deployment that could well follow U.S. deployment might not share the same defensive goal or the same technology, stimulating the usual anxieties about unequal intentions and capabilities. Defensive systems are also complex, leading different analysts to widely different conclusions about the likely wartime performance of the BMD systems on both sides. Moreoever the owner of the BMD, aware of all the system's hidden flaws, might credit it with little capability, whereas the offense planner will tend to give it the benefit of the doubt. Though some hypothetical future world with mutual BMD deployments might therefore appeal to one analyst or nation, another could easily have a completely different view of the technical and strategic "facts."

Section 10
PRINCIPAL JUDGMENTS AND OBSERVATIONS

1. **The prospect that emerging "Star Wars" technologies, when further developed, will provide a perfect or near-perfect defense system, literally removing from the hands of the Soviet Union the ability to do socially mortal damage to the United States with nuclear weapons, is so remote that it should not serve as the basis of public expectation or national policy about ballistic missile defense (BMD).** This judgment appears to be the consensus among informed members of the defense technical community.

Technical prognosis for such a perfect or near-perfect defense is extremely pessimistic because of the concentration and fragility of society; because all concepts identified as candidates for a future defense of population are known to be susceptible to countermeasures that would permit the Soviet Union to retain a degree of penetration with their future missile arsenal despite costly attempts to improve the U.S. defense; because the Soviet Union would almost certainly make such a determined effort to avoid being disarmed by a U.S. defense; and because missile defense does not address other methods for delivering nuclear weapons to the United States.

Mutual assured destruction (MAD), if this term is applied to a state of technological existence rather than to a chosen national policy, is likely to persist for the foreseeable future.

2. **The wisdom of deploying less-than-perfect ballistic missile defenses remains controversial.** Less-than-perfect defenses would still allow the Soviet Union to destroy U.S. society in a massive attack but might call into question the effectiveness of smaller, specialized nuclear strikes.

Certain theories about nuclear war maintain that such defenses could lessen the chances of nuclear war and enhance U.S. security by protecting U.S. retaliatory forces; by interdicting "limited" nuclear strikes; by further confusing Soviet predictions of the outcome of a strike; by driving Soviet missile deployments in directions favored by the United States; by lessening the consequences of nuclear attack; and/or by fulfilling still other strategic goals.

Critics dispute the validity of some of these goals; dispute that technology can fulfill the truly useful goals; and/or argue that the many harmful side effects of introducing BMD to the strategic equation and altering the Anti-Ballistic Missile (ABM) Treaty regime are not worth satisfying these goals.

To address the wisdom of less-than-perfect defense, the public and policymakers would need a precise statement of the strategic goal of the deployment, an assessment of whether technology could satisfy that goal, and an analysis balancing fulfillment of the goal against the side effects and uncertainties of introducing a new ingredient into the strategic nuclear arena.

3. **The strategic goal of President Reagan's Strategic Defense Initiative calling for emphasized BMD research—perfect, near-perfect, or less-than-perfect defense against ballistic missiles—remains unclear.** No explicit technical standards or criteria are therefore available against which to measure the technological prospects and progress of this initiative.

4. **In all cases, directed-energy weapons and other devices with the specifications needed for boost-phase intercept of ICBMs have not yet been built in the laboratory, much less in a form suitable for incorporation in a complete defense system.** These devices include chemical lasers, excimer and free electron lasers, x-ray lasers, particle beams, lightweight high-velocity kinetic energy weapons, and microwave generators, together with tracking, aiming, and pointing mechanisms, power sources, and other essential accompaniments.

It is unknown whether or when devices with the required specifications can be built.

5. **Moreover, making the technological devices perform to the needed specifications in a controlled situation is not the crux of the technical challenge facing designers of an effective ballistic missile defense. A distinct challenge is to fashion from these devices a reliable defensive architecture, taking into account vulnerability**

of the defense components, susceptibility to future Soviet countermeasures, and cost relative to those countermeasures.

New intercept mechanisms—directed energy weapons and the like—therefore do not by themselves necessarily herald dramatically new BMD capabilities.

6. **It is clear that potent directed-energy weapons will be developed for other military purposes, even if such weapons are never incorporated into effective BMDs.** Such weapons might have a role in nuclear offense as well as defense, in anti-satellite (ASAT) attack, in anti-aircraft attack, and in other applications of concern to nuclear policy and arms control. Defense and arms control policy will thus need to face the advent of these new weapons, irrespective of their BMD dimension.

7. **For modest defensive goals requiring less-than-perfect performance, traditional reentry phase defenses and/or more advanced mid-course defenses might suffice.** Such defenses present less technical risk than systems that incorporate a boost-phase layer, and they could probably be deployed more quickly.

New ideas for improving such "old" BMD concepts have emerged in the atmosphere of technical optimism enjoyed by the boost-phase concepts.

8. **Deployment of missile defenses based on new technologies is forbidden by the Anti-Ballistic Missile (ABM) Treaty reached at SALT I.** The Treaty permits only restricted deployment of traditional BMDs using fixed, ground-based radars and interceptor missiles. Research into new technologies, and in selected cases development and testing of defense systems based on these technologies, are allowed within the Treaty.

9. **There is a close connection, not explored in detail in this Background Paper, between advanced BMD concepts and future anti-satellite (ASAT) systems.** This connection springs from four observations: 1) ASAT attack on space-based weapons and sensors is probably the most attractive countermeasure to boost-phase BMD; 2) directed-energy weapons are more likely to succeed in the easier mission of ASAT than in the more difficult mission of boost-phase BMD; 3) to a degree dependent on technical details, early stages of development of boost phase BMDs might be conducted in the guise of ASAT development, stimulating anxieties about the health of the ABM Treaty regime; 4) to a degree dependent on technical details, concluding a treaty with the Soviet Union limiting ASAT development would impede BMD research at an earlier stage than would occur under the terms of the ABM Treaty alone.

APPENDIX A: THE CONCLUSION OF PRESIDENT REAGAN'S MARCH 23, 1983, SPEECH ON DEFENSE SPENDING AND DEFENSIVE TECHNOLOGY

Weekly Compilation of

Presidential Documents

Monday, March 28, 1983
Volume 19—Number 12
Pages 423–466

Now, thus far tonight I've shared with you my thoughts on the problems of national security we must face together. My predecessors in the Oval Office have appeared before you on other occasions to describe the threat posed by Soviet power and have proposed steps to address that threat. But since the advent of nuclear weapons, those steps have been increasingly directed toward deterrence of aggression through the promise of retaliation.

This approach to stability through offensive threat has worked. We and our allies have succeeded in preventing nuclear war for more than three decades. In recent months, however, my advisers, including in particular the Joint Chiefs of Staff, have underscored the necessity to break out of a future that relies solely on offensive retaliation for our security.

Over the course of these discussions, I've become more and more deeply convinced that the human spirit must be capable of rising above dealing with other nations and human beings by threatening their existence. Feeling this way, I believe we must thoroughly examine every opportunity for reducing tensions and for introducing greater stability into the strategic calculus on both sides.

One of the most important contributions we can make is, of course, to lower the level of all arms, and particularly nuclear arms. We're engaged right now in several negotiations with the Soviet Union to bring about a mutual reduction of weapons. I will report to you a week from tomorrow my thoughts on that score. But let me just say, I'm totally committed to this course.

If the Soviet Union will join with us in our effort to achieve major arms reduction, we will have succeeded in stabilizing the nuclear balance. Nevertheless, it will still be necessary to rely on the specter of retaliation, on mutual threat. And that's a sad commentary on the human condition. Wouldn't it be better to save lives than to avenge them? Are we not capable of demonstrating our peaceful intentions by applying all our abilities and our ingenuity to achieving a truly lasting stability? I think we are. Indeed, we must.

After careful consultation with my advisers, including the Joint Chiefs of Staff, I believe there is a way. Let me share with you a vision of the future which offers hope. It is that we embark on a program to counter the awesome Soviet missile threat with measures that are defensive. Let us turn to the very strengths in technology that spawned our great industrial base and that have given us the quality of life we enjoy today.

What if free people could live secure in the knowledge that their security did not rest upon the threat of instant U.S. retaliation to deter a Soviet attack, that we could intercept and destroy strategic ballistic missiles before they reached our own soil or that of our allies?

I know this is a formidable, technical task, one that may not be accomplished before the end of this century. Yet, current technology has attained a level of sophistication where it's reasonable for us to begin this effort. It will take years, probably decades of effort on many fronts. There will be failures and setbacks, just as there will be successes and breakthroughs. And as we proceed, we must remain constant in preserving the nuclear deterrent and maintaining a solid capability for flexible response. But isn't it worth every investment necessary to free the world from the threat of nuclear war? We know it is.

In the meantime, we will continue to pursue real reductions in nuclear arms, negotiating from a position of strength that can be ensured only by modernizing our strategic forces. At the same time, we must take steps to reduce the risk of a conventional military conflict escalating to nuclear war by improving our non-nuclear capabilities.

America does possess—now—the technologies to attain very significant improvements in the effectiveness of our conventional, non-nuclear forces. Proceeding boldly with these new technologies, we can significantly reduce any incentive that the Soviet Union may have to threaten attack against the United States or its allies.

As we pursue our goal of defensive technologies, we recognize that our allies rely upon our strategic offensive power to deter attacks against them. Their vital interests and ours are inextricably linked. Their safety and ours are one. And no change in technology can or will alter that reality. We must and shall continue to honor our commitments.

I clearly recognize that defensive systems have limitations and raise certain problems and ambiguities. If paired with offensive systems, they can be viewed as fostering an aggressive policy, and no one wants that. But with these considerations firmly in mind, I call upon the scientific community in our country, those who gave us nuclear weapons, to turn their great talents now to the cause of mankind and world peace, to give us the means of rendering these nuclear weapons impotent and obsolete.

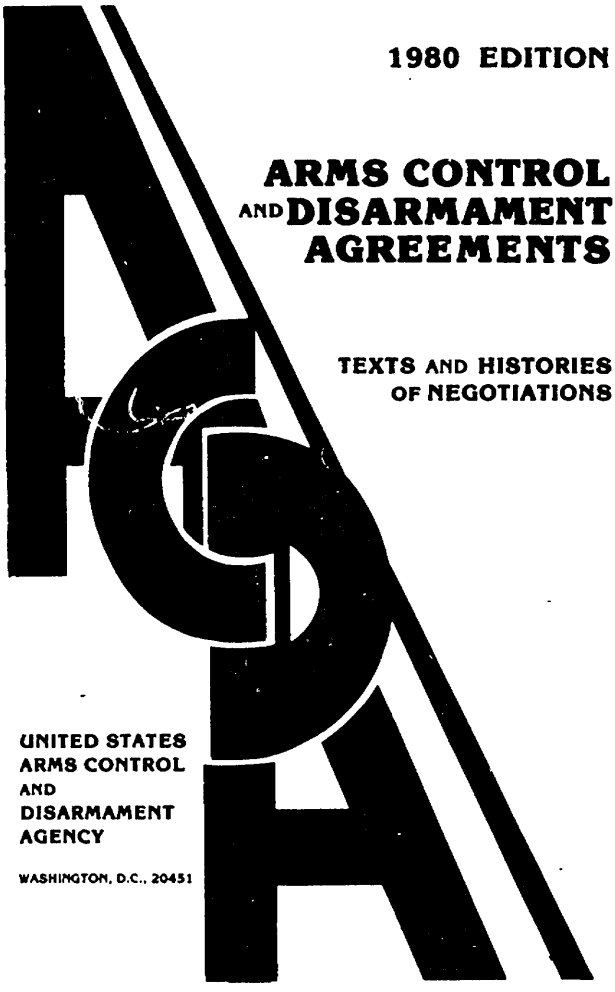
Tonight, consistent with our obligations of the ABM treaty and recognizing the need for closer consultation with our allies, I'm taking an important first step. I am directing a comprehensive and intensive effort to define a long-term research and development program to begin to achieve our ultimate goal of eliminating the threat posed by strategic nuclear missiles. This could pave the way for arms control measures to eliminate the weapons themselves. We seek neither military superiority nor political advantage. Our only purpose—one all people share—is to search for ways to reduce the danger of nuclear war.

My fellow Americans, tonight we're launching an effort which holds the promise of changing the course of human history. There will be risks, and results take time. But I believe we can do it. As we cross this threshold, I ask for your prayers and your support.

Thank you, good night, and God bless you.

Note: The President spoke at 8:02 p.m. from the Oval Office at the White House. The address was broadcast live on nationwide radio and television.

Following his remarks, the President met in the White House with a number of administration officials, including members of the Cabinet, the White House staff, and the Joint Chiefs of Staff, and former officials of past administrations to discuss the address.


1980 EDITION
ARMS CONTROL
AND DISARMAMENT
AGREEMENTS
TEXTS AND HISTORIES
OF NEGOTIATIONS
UNITED STATES
ARMS CONTROL
AND
DISARMAMENT
AGENCY
WASHINGTON, D.C., 20451

Treaty Between the United States of America and the Union of Soviet Socialist Republics on the Limitation of Anti-Ballistic Missile Systems

Signed at Moscow May 26, 1972
Ratification advised by U.S. Senate August 3, 1972
Ratified by U.S. President September 30, 1972
Proclaimed by U.S. President October 3, 1972
Instruments of ratification exchanged October 3, 1972
Entered into force October 3, 1972

The United States of America and the Union of Soviet Socialist Republics, hereinafter referred to as the Parties,

Proceeding from the premise that nuclear war would have devastating consequences for all mankind,

Considering that effective measures to limit anti-ballistic missile systems would be a substantial factor in curbing the race in strategic offensive arms and would lead to a decrease in the risk of outbreak of war involving nuclear weapons,

Proceeding from the premise that the limitation of anti-ballistic missile systems, as well as certain agreed measures with respect to the limitation of strategic offensive arms, would contribute to the creation of more favorable conditions for further negotiations on limiting strategic arms,

Mindful of their obligations under Article VI of the Treaty on the Non-Proliferation of Nuclear Weapons,

Declaring their intention to achieve at the earliest possible date the cessation of the nuclear arms race and to take effective measures toward reductions in strategic arms, nuclear disarmament, and general and complete disarmament,

Desiring to contribute to the relaxation of international tension and the strengthening of trust between States,

Have agreed as follows

Article I

1. Each party undertakes to limit anti-ballistic missile (ABM) systems and to adopt other measures in accordance with the provisions of this Treaty.

2. Each Party undertakes not to deploy ABM systems for a defense of the territory of its country and not to provide a base for such a defense, and not to deploy ABM systems for defense of an individual region except as provided for in Article III of this Treaty

Article II

1. For the purpose of this Treaty an ABM system is a system to counter strategic ballistic missiles or their elements in flight trajectory, currently consisting of:

(a) ABM interceptor missiles, which are interceptor missiles constructed and deployed for an ABM role, or of a type tested in an ABM mode,

(b) ABM launchers, which are launchers constructed and deployed for launching ABM interceptor missiles; and

(c) ABM radars, which are radars constructed and deployed for an ABM role, or of a type tested in an ABM mode.

2. The ABM system components listed in paragraph 1 of this Article include those which are.

(a) operational;
(b) under construction,
(c) undergoing testing,
(d) undergoing overhaul, repair or conversion, or
(e) mothballed.

Article III

Each Party undertakes not to deploy ABM systems or their components except that

(a) within one ABM system deployment area having a radius of one hundred and fifty kilometers and centered on the Party's national capital, a Party may deploy (1) no more than one hundred ABM launchers and no more than one hundred ABM interceptor missiles at launch sites, and (2) ABM radars within no more than six ABM radar complexes, the area of each complex being circular and having a diameter of no more than three kilometers, and

(b) within one ABM system deployment area having a radius of one hundred and fifty kilometers and containing ICBM silo launchers, a Party may deploy, (1) no more than one hundred ABM launchers and no more than one hundred ABM interceptor missiles at launch sites, (2) two large phased-array ABM radars comparable in potential to corresponding ABM radars operational or under construction on the date of signature of the Treaty in an ABM system deployment area containing ICBM silo launchers, and (3) no more than eighteen ABM radars each having a potential less than the potential of the smaller of the above-mentioned two large phased-array ABM radars.

Article IV

The limitations provided for in Article III shall not apply to ABM systems or their components used for development or testing, and located within current or additionally agreed test ranges Each Party may have no more than a total of fifteen ABM launchers at test ranges

Article V

1 Each Party undertakes not to develop, test, or deploy ABM systems or components which are sea-based, air-based, space-based, or mobile land-based

2 Each Party undertakes not to develop, test, or deploy ABM launchers for launching more than one ABM interceptor missile at a time from each launcher, not to modify deployed launchers to provide them with such a capability, not to develop, test, or deploy automatic or semi-automatic or other similar systems for rapid reload of ABM launchers.

Article VI

To enhance assurance of the effectiveness of the limitations on ABM systems and their components provided by the Treaty, each Party undertakes

(a) not to give missiles, launchers, or radars, other than ABM interceptor missiles, ABM launchers, or ABM radars, capabilities to counter strategic ballistic missiles or their elements in flight trajectory, and not to test them in an ABM mode, and

(b) not to deploy in the future radars for early warning of strategic ballistic missile attack except at locations along the periphery of its national territory and oriented outward.

Article VII

Subject to the provisions of this Treaty, modernization and replacement of ABM systems or their components may be carried out.

Article VIII

ABM systems or their components in excess of the numbers or outside the areas specified in this Treaty, as well as ABM systems or their components prohibited by this Treaty, shall be destroyed or dismantled under agreed procedures within the shortest possible agreed period of time.

Article IX

To assure the viability and effectiveness of this Treaty, each Party undertakes not to transfer to other States, and not to deploy outside its national territory, ABM systems or their components limited by this Treaty.

Article X

Each Party undertakes not to assume any international obligations which would conflict with this Treaty.

Article XI

The Parties undertake to continue active negotiations for limitations on strategic offensive arms.

Article XII

1. For the purpose of providing assurance of compliance with the provisions of this Treaty, each Party shall use national technical means of verification at its disposal in a manner consistent with generally recognized principles of international law.

2. Each Party undertakes not to interfere with the national technical means of verification of the other Party operating in accordance with paragraph 1 of this Article.

3. Each Party undertakes not to use deliberate concealment measures which impede verification by national technical means of compliance with the provisions of this Treaty. This obligation shall not require changes in current construction, assembly, conversion, or overhaul practices.

Article XIII

1. To promote the objectives and implementation of the provisions of this Treaty, the Parties shall establish promptly a Standing Consultative Commission, within the framework of which they will:

(a) consider questions concerning compliance with the obligations assumed and related situations which may be considered ambiguous;

(b) provide on a voluntary basis such information as either Party considers necessary to assure confidence in compliance with the obligations assumed;

(c) consider questions involving unintended interference with national technical means of verification;

(d) consider possible changes in the strategic situation which have a bearing on the provisions of this Treaty;

(e) agree upon procedures and dates for destruction or dismantling of ABM systems or their components in cases provided for by the provisions of this Treaty;

(f) consider, as appropriate, possible proposals for further increasing the viability of this Treaty, including proposals for amendments in accordance with the provisions of this Treaty;

(g) consider, as appropriate, proposals for further measures aimed at limiting strategic arms.

2. The Parties through consultation shall establish, and may amend as appropriate, Regulations for the Standing Consultative Commission governing procedures, composition and other relevant matters.

Article XIV

1. Each Party may propose amendments to this Treaty. Agreed amendments shall enter into force in accordance with the procedures governing the entry into force of this Treaty.

2. Five years after entry into force of this Treaty, and at five-year intervals thereafter, the Parties shall together conduct a review of this Treaty.

Article XV

1. This Treaty shall be of unlimited duration.

2. Each Party shall, in exercising its national sovereignty, have the right to withdraw from this Treaty if it decides that extraordinary events related to the subject matter of this Treaty have jeopardized its supreme interests. It shall give notice of its decision to the other Party six months prior to withdrawal from the Treaty. Such notice shall include a statement of the extraordinary events the notifying Party regards as having jeopardized its supreme interests.

Article XVI

1. This Treaty shall be subject to ratification in accordance with the constitutional procedures of each Party. The Treaty shall enter into force on the day of the exchange of instruments of ratification.

2. This Treaty shall be registered pursuant to Article 102 of the Charter of the United Nations.

DONE at Moscow on May 26, 1972, in two copies, each in the English and Russian languages, both texts being equally authentic.

FOR THE UNITED STATES OF AMERICA

President of the United States of America

FOR THE UNION OF SOVIET SOCIALIST REPUBLICS

General Secretary of the Central Committee of the CPSU

Agreed Statements, Common Understandings, and Unilateral Statements Regarding the Treaty Between the United States of America and the Union of Soviet Socialist Republics on the Limitation of Anti-Ballistic Missiles

1. Agreed Statements

The document set forth below was agreed upon and initialed by the Heads of the Delegations on May 26, 1972 (letter designations added).

AGREED STATEMENTS REGARDING THE TREATY BETWEEN THE UNITED STATES OF AMERICA AND THE UNION OF SOVIET SOCIALIST REPUBLICS ON THE LIMITATION OF ANTI-BALLISTIC MISSILE SYTEMS

[A]

The Parties understand that, in addition to the ABM radars which may be deployed in accordance with subparagraph (a) of Article III of the Treaty, those non-phased-array ABM radars operational on the date of signature of the Treaty within the ABM system deployment area for defense of the national capital may be retained.

[B]

The Parties understand that the potential (the product of mean emitted power in watts and antenna area in square meters) of the smaller of the two large phased-array ABM radars referred to in subparagraph (b) of Article III of the Treaty is considered for purposes of the Treaty to be three million.

[C]

The Parties understand that the center of the ABM system deployment area centered on the national capital and the center of the ABM system deployment area containing ICBM silo launchers for each Party shall be separated by no less than thirteen hundred kilometers.

[D]

In order to insure fulfillment of the obligation not to deploy ABM systems and their components except as provided in Article III of the Treaty, the Parties agree that in the event ABM systems based on other physical principles and including components capable of substituting for ABM interceptor missiles, ABM launchers, or ABM radars are created in the future, specific limitations on such systems and their components would be subject to discussion in accordance with Article XIII and agreement in accordance with Article XIV of the Treaty.

[E]

The Parties understand that Article V of the Treaty includes obligations not to develop, test or deploy ABM interceptor missiles for the delivery by each ABM interceptor missile of more than one independently guided warhead.

[F]

The Parties agree not to deploy phased-array radars having a potential (the product of mean emitted power in watts and antenna area in square meters) exceeding three million, except as provided for in Articles III, IV and VI of the Treaty, or except for the purposes of tracking objects in outer space or for use as national technical means of verification.

[G]

The Parties understand that Article IX of the Treaty includes the obligation of the US and the USSR not to provide to other States technical descriptions or blue prints specially worked out for the construction of ABM systems and their components limited by the Treaty.

2. Common Understandings

Common understanding of the Parties on the following matters was reached during the negotiations:

A. Location of ICBM Defenses

The U.S. Delegation made the following statement on May 26, 1972:

Article III of the ABM Treaty provides for each side one ABM system deployment area centered on its national capital and one ABM system deployment area containing ICBM silo launchers. The two sides have registered agreement on the following statement: "The Parties understand that the center of the ABM system deployment area centered on the national capital and the center of the ABM system deployment area containing ICBM silo launchers for each Party shall be separated by no less than thirteen hundred kilometers." In this connection, the U.S. side notes that its ABM system deployment area for defense of ICBM silo launchers, located west of the Mississippi River, will be centered in the Grand Forks ICBM silo launcher deployment area. (See Agreed Statement [C].)

B. ABM Test Ranges

The U.S. Delegation made the following statement on April 26, 1972:

Article IV of the ABM Treaty provides that "the limitations provided for in Article III shall not apply to ABM systems or their components used for development or testing, and located within current or additionally agreed test ranges." We believe it would be useful to assure that there is no misunderstanding as to current ABM test ranges. It is our understanding that ABM test ranges encompass the area within which ABM components are located for test purposes. The current U.S. ABM test ranges are at White Sands, New Mexico, and at Kwajalein Atoll, and the current Soviet ABM test range is near Sary Shagan in Kazakhstan. We consider that non-phased array radars of types used for range safety or instrumentation purposes may be located outside of ABM test ranges. We interpret the reference in Article IV to "additionally agreed test

ranges" to mean that ABM components will not be located at any other test ranges without prior agreement between our Governments that there will be such additional ABM test ranges

On May 5, 1972, the Soviet Delegation stated that there was a common understanding on what ABM test ranges were, that the use of the types of non-ABM radars for range safety or instrumentation was not limited under the Treaty, that the reference in Article IV to "additionally agreed" test ranges was sufficiently clear, and that national means permitted identifying current test ranges.

C Mobile ABM Systems

On January 29, 1972, the U S Delegation made the following statement

Article V(1) of the Joint Draft Text of the ABM Treaty includes an undertaking not to develop, test, or deploy mobile land-based ABM systems and their components On May 5, 1971, the U S side indicated that, in its view, a prohibition on deployment of mobile ABM systems and components would rule out the deployment of ABM launchers and radars which were not permanent fixed types At that time, we asked for the Soviet view of this interpretation Does the Soviet side agree with the U S. side's interpretation put forward on May 5, 1971?

On April 13, 1972, the Soviet Delegation said there is a general common understanding on this matter

D Standing Consultative Commission

Ambassador Smith made the following statement on May 22, 1972

The United States proposes that the sides agree that, with regard to initial implementation of the ABM Treaty's Article XIII on the Standing Consultative Commission (SCC) and of the consultation Articles to the Interim Agreement on offensive arms and the Accidents Agreement,[1] agreement establishing the SCC will be worked out early in the follow-on SALT negotiations, until that is completed, the following arrangements will prevail when SALT is in session, any consultation desired by either side under these Articles can be carried out by the two SALT Delegations, when SALT is not in session, *ad hoc* arrangements for any desired consultations under these Articles may be made through diplomatic channels

Minister Semenov replied that on an *ad referendum* basis, he could agree that the U S statement corresponded to the Soviet understanding

E Standstill

On May 6, 1972, Minister Semenov made the following statement

In an effort to accommodate the wishes of the U S side, the Soviet Delegation is prepared to proceed on the basis that the two sides will in fact observe the obligations of both the Interim Agreement and the ABM Treaty beginning from the date of signature of these two documents

In reply, the U S Delegation made the following statement on May 20, 1972

[1] See Article 7 of Agreement to Reduce the Risk of Outbreak of Nuclear War Between the United States of America and the Union of Soviet Socialist Republics, signed Sept 30, 1971

The U S agrees in principle with the Soviet statement made on May 6 concerning observance of obligations beginning from date of signature but we would like to make clear our understanding that this means that, pending ratification and acceptance, neither side would take any action prohibited by the agreements after they had entered into force This understanding would continue to apply in the absence of notification by either signatory of its intention not to proceed with ratification or approval

The Soviet Delegation indicated agreement with the U S statement

3. Unilateral Statements

The following noteworthy unilateral statements were made during the negotiations by the United States Delegation

A Withdrawal from the ABM Treaty

On May 9, 1972, Ambassador Smith made the following statement.

The U S Delegation has stressed the importance the U S Government attaches to achieving agreement on more complete limitations on strategic offensive arms following agreement on an ABM Treaty and on an Interim Agreement on certain measures with respect to the limitation of strategic offensive arms The U S Delegation believes that an objective of the follow-on negotiations should be to constrain and reduce on a long-term basis threats to the survivability of our respective strategic retaliatory forces The USSR Delegation has also indicated that the objectives of SALT would remain unfulfilled without the achievement of an agreement providing for more complete limitations on strategic offensive arms. Both sides recognize that the initial agreements would be steps toward the achievement of more complete limitations on strategic arms. If an agreement providing for more complete strategic offensive arms limitations were not achieved within five years, U S supreme interests could be jeopardized Should that occur, it would constitute a basis for withdrawal from the ABM Treaty The U S does not wish to see such a situation occur, nor do we believe that the USSR does It is because we wish to prevent such a situation that we emphasize the importance the U S Government attaches to achievement of more complete limitations on strategic offensive arms The U S Executive will inform the Congress, in connection with Congressional consideration of the ABM Treaty and the Interim Agreement, of this statement of the U S. position

B Tested in ABM Mode

On April 7, 1972, the U S. Delegation made the following statement

Article II of the Joint Text Draft uses the term "tested in an ABM mode," in defining ABM components, and Article VI includes certain obligations concerning such testing We believe that the sides should have a common understanding of this phrase. First, we would note that the testing provisions of the ABM Treaty are intended to apply to testing which occurs after the date of signature of the Treaty, and not to any testing which may have occurred in the past Next, we would amplify the remarks we have made on this subject during the previous Helsinki phase by setting forth the objectives which govern the U S. view on the subject, namely, while prohibiting testing of non-ABM components for ABM purposes, not to prevent testing of ABM components, and not to prevent testing of non-ABM components for

non-ABM purposes. To clarify our interpretation of "tested in an ABM mode" we note that we would consider a launcher, missile or radar to be "tested in an ABM mode" if, for example, any of the following events occur: (1) a launcher is used to launch an ABM interceptor missile; (2) an interceptor missile is flight tested against a target vehicle which has a flight trajectory with characteristics of a strategic ballistic missile flight trajectory, or is flight tested in conjunction with the test of an ABM interceptor missile or an ABM radar at the same test range, or is flight tested to an altitude inconsistent with interception of targets against which air defenses are deployed; (3) a radar makes measurements on a cooperative target vehicle of the kind referred to in item (2) above during the reentry portion of its trajectory or makes measurements in conjunction with the test of an ABM interceptor missile or an ABM radar at the same test range. Radars used for purposes such as range safety or instrumentation would be exempt from application of these criteria.

C. No-Transfer Article of ABM Treaty

On April 18, 1972, the U.S. Delegation made the following statement:

In regard to this Article [IX], I have a brief and I believe self-explanatory statement to make. The U.S. side wishes to make clear that the provisions of this Article do not set a precedent for whatever provision may be considered for a Treaty on Limiting Strategic Offensive Arms. The question of transfer of strategic offensive arms is a far more complex issue, which may require a different solution.

D. No Increase in Defense of Early Warning Radars

On July 28, 1970, the U.S. Delegation made the following statement:

Since Hen House radars [Soviet ballistic missile early warning radars] can detect and track ballistic missile warheads at great distances, they have a significant ABM potential. Accordingly, the U.S. would regard any increase in the defenses of such radars by surface-to-air missiles as inconsistent with an agreement.

APPENDIX C: OTHER APPLICATIONS OF DIRECTED ENERGY WEAPONS

This Background Paper treats only one—and probably one of the most difficult—military application of directed energy. Many other applications of widely varying plausibility vie for funding and attention. An assessment of all these schemes is well beyond the scope of this Paper, but the list below is provided for reference. Mention of a scheme does not imply that it has any technical or military promise; this question would have to be properly studied.

Anti-satellite (ASAT). Directed energy attack on satellites from space-, air-, or ground-based weapons is substantially easier than boost phase BMD. A satellite's orbit is completely predictable, making it in effect a fixed target. Long dwell times and low fluences suffice for ASAT attack on unshielded satellites. For instance, long illumination at just a few watts/cm^2 (several times the sun's normal irradiance in space) could upset the thermal control systems that allow spacecraft to endure the extremes of heat and cold in outer space. Substantial hardening of large and complex satellites (including sensors) to directed energy weapons from all directions at all times is impractical. Unlike BMD, which must handle thousands of boosters in a few minutes, ASATs would have fewer targets and longer attack times. Last, BMDs must operate under the most hostile circumstances imaginable, whereas the superpowers might use ASATs in scenarios short of nuclear war.

This Background Paper has stressed (see Section 5.1) that maturation of the same technologies involved in boost phase BMD virtually assures potent ASATs. The so-called "Star Wars" systems could well be their own worst threats. Besides the intrinsic ease of ASAT over BMD, a Soviet defense suppression ASAT attack on U.S. defensive battle stations would have three key factors working in its favor: 1) The Soviets would pick the time and sequence of attack on the U.S. BMD system and launch of their ICBMs; 2) The Soviets need not destroy the entire defensive constellation, but only "punch a hole" for their ICBMs to pass through; 3) The attack would take place over Soviet territory.

Ground-based laser ASATs, presumably using excimer or free-electron lasers for best atmospheric propagation, would have the advantages of large size and power supplies. Airborne lasers could avoid some of the propagation disturbances introduced by denser air at low altitudes, but turbulence around the airplane skin could require adaptive beam compensation.

Space-based directed energy ASATs are the most interesting category of all, since they would be, in effect, long-range space mines. Rather than positioning itself next to its quarry like an ordinary space mine, a laser could be thousands of kilometers away and still be able to strike within milliseconds upon receipt of a radio signal from the gound.

Strategic offense. If they mature, the directed energy devices discussed for BMD might turn out to have been better termed "offensive breakthroughs" than "defensive breakthroughs." Consider, for example, a fleet of Soviet x-ray lasers launched simultaneously with (or minutes before) a Soviet first-stike ICBM attack. The pop-up x-ray lasers' job would be to intercept any U.S. ICBMs launched before arrival of Soviet silo-killing RVs. The Soviet x-ray lasers would therefore deprive the U.S. of its option for launch under attack. Microwave generators might be used for EMP-like attack on the U.S. command and control system. Another example of offensive use of beam weapons would be Soviet ASAT attack on U.S. warning, communications, nuclear detonation detection, or navigation satellites important to the U.S. ratalatory capability. Yet another example would of course be suppression of any U.S. BMD that used space-based weapons or sensors.

Bus intercept. This Background Paper has focused on intercept of ICBMs before booster burnout. Intercept of the bus or post boost vehicle poses a rather different challenge. Post-boost phase for today's ICBMs is rather long (several minutes) but could be shortened drastically on future ICBMs. Bus tracking requires a different sensor than booster tracking, since the bus plume

is much less conspicuous, and the bus rocket motor may not operate continuously. The bus is a target of declining value as it dispenses its RVs. Interruption of bus operation would not prevent the bus and its contents from continuing their ballistic flight to the target country, though the aim might be very wide of the target. Operating above the atmosphere, the bus can deploy lightweight shields, decoys, and sensor countermeasures (e.g., corner reflectors). On the other hand, x-ray lasers and neutral particle beams that cannot penetrate the atmosphere can attack the bus in space.

Anti-SLBM. A number of schemes have been suggested for using directed energy weapons against SLBMs, besides the obvious extensions of ICBM defense. Thus pop-up x-ray lasers could be positioned on U.S. coasts or ships at sea to intercept SLBMs launched from nearby Soviet submarines. Aircraft patrolling coastal waters and carrying lasers could attack ascending SLBMs in their area.

Anti-IRBM. Intermediate range ballistic missiles (IRBMs) have short boost phases and potentially low trajectories, making anti-IRBM defense rather different from anti-ICBM defense and perhaps better accomplished with ground-based terminal BMD systems deployed in the theater.

Defense of satellites (DSAT). Low-power wide-divergence (small optics) laser satellites (perhaps HF for high specific energy) could serve as "escorts" for other satellites, defending the other satellites from hostile objects—mines, ASAT missiles —approaching within a given range.

Anti-aircraft. At least four schemes have been broached for using directed energy weapons against aircraft or cruise missiles. The most ambitious would involve a worldwide constellation of trackers (possibly LWIR) and beam weapons (possibly DF or short wavelength lasers) to attack Soviet Blackjack strategic bombers, Backfire bombers attacking U.S. aircraft carriers, Soviet airborne command post "Doomsday planes," Soviet AWACS radar planes, and so on. In a second scheme, B-1 or B-52 bombers would be outfitted with lasers (possibly DF) to protect them from Soviet fighters, surface-to-air missiles (SAMs), and air-to-air missiles. A third scheme equips carrier battle groups with lasers or particle beams to defend themselves against cruise missile attack. Fourth and last, ground-based beam weapons might replace surface-to-air missiles for local air defense.

Midcourse and terminal BMD. Intense electron beams have long been studied as replacements for interceptors in reentry BMD. In midcourse BMD, beam weapons might not only destroy RVs, but aid discrimination of RVs from lightweight decoys: lasers, particle beams, or x-ray lasers would illuminate approaching objects, and sensors would use the response of each object as an extra piece of data to judge whether it was a true RV (see Section 6).

Submarine communications. This scheme would use a blue-green laser to communicate with submerged submarines. Seawater is opaque to all but VLF and ELF radio frequencies, used for submarine communications today, and to the blue-green portion of the visible light spectrum. A blue-green laser beam originating on a satellite, reflected from a space-based mirror, or carried by an airplane would be modulated in accordance with the message to be transmitted and directed at a given spot on the ocean. After transmission of the full message, the beam would dwell on a neighboring spot and transmit again, and so on, eventually covering all submarine patrol areas. Optical sensors on the submarine hull would detect the message.

Blinding sensors and seekers. Analysts have studied a wide range of tactical applications for lasers, involving blinding of battlefield sensors, missile seekers, and even human beings.



Office of Technology Assessment

The Office of Technology Assessment (OTA) was created in 1972 as an analytical arm of Congress. OTA's basic function is to help legislative policymakers anticipate and plan for the consequences of technological changes and to examine the many ways, expected and unexpected, in which technology affects people's lives. The assessment of technology calls for exploration of the physical, biological, economic, social, and political impacts that can result from applications of scientific knowledge. OTA provides Congress with independent and timely information about the potential effects—both beneficial and harmful—of technological applications.

Requests for studies are made by chairmen of standing committees of the House of Representatives or Senate; by the Technology Assessment Board, the governing body of OTA; or by the Director of OTA in consultation with the Board.

The Technology Assessment Board is composed of six members of the House, six members of the Senate, and the OTA Director, who is a nonvoting member.

OTA has studies under way in nine program areas: energy and materials; industry, technology, and employment; international security and commerce; biological applications; food and renewable resources; health; communication and information technologies; oceans and environment; and science, transportation, and innovation.

Senator PRESSLER. One question which has been raised about this excellent study is what authority does it have? Is it just one man's opinion?

I want to get to the bottom of this question of authority. I know the author is Ashton B. Carter of MIT. People have asked why did we not find a conservative institution? I do not know if MIT is liberal or conservative. But still, the question is how authoritative is this study? Does this represent the thinking of scientists in the area? What checks were there to insure its authority? Was it reviewed by experts? What process did you go through technically?

Mr. GIBBONS. Let me make a brief response, and then ask my colleagues if they might volunteer.

First of all, it is not an opinion, it is an analysis. And there is a difference.

Senator PRESSLER. It is an analysis.

Mr. GIBBONS. It is an analysis.

Senator PRESSLER. And how does that vary from an opinion?

Mr. GIBBONS. Well, an analysis means that you have written down and made quite explicit your assumptions and your methods of calculation and how you got to your conclusions and your sources of information.

Senator PRESSLER. That is an analysis.

Mr. GIBBONS. That is an analysis.

A statement of opinion——

Senator PRESSLER. This is a statement of opinion?

Mr. GIBBONS. No, this is not a statement of opinion. This is an analysis which draws on facts that people can agree about, uses methods of calculation which are transparent, that is, they are well understood, and then draws conclusions.

Now, to that extent, whether it is written by the world's greatest liberal or the world's greatest conservative, it seems to me, is only a minor, secondary matter because it starts from an analytical base.

The second thing is that the paper has been reviewed, and I think there are some credits in front of it—by a number of other scholars, and we have attempted to find as many criticisms as we can up to this point, and we have found some, and they are incorporated in the paper, in short, it has gone through the review process among technical peers, and those reviews have been incorporated. We have invited comments from experts in many different fields, and we have benefited from that review process.

Third, I would say that even though we have gone through the process of these calculations and peer review before we finished the document for you, the paper is less comprehensive than an OTA assessment, that is, it is a more narrowly focused paper than a typical assessment at OTA which looks more broadly at an issue and takes into account more of the variety of concerns associated with it.

But I think the strongest assurance that you can have about its authority is not only the qualifications of the author but the review process that the paper went through.

Might I ask my colleagues, do you want to add to that?

[No response.]

Mr. GIBBONS. If you would like, Dr. Carter could tell you in just a few moments about how we went about the study.

Senator PRESSLER. Yes, how did you go about conducting the study?

Mr. CARTER. I think everything Jack said is right, but as you said, it is not a committee report, it is not a group of wise people that got together and jointly drafted this. I drafted it myself. But I did spend the last 6 months or so on the road at the laboratories, Los Alamos, Livermore, and so forth, where the work is done, where I know people, the scientists really doing the work, and all of them that I have talked to looked at this before it was published. So I had plenty of time to take their opinion into account.

So insofar as the defense science community is concerned, both inside the Government and outside, I feel comfortable that I ran things by them, and I am aware of what they are doing. They are, of course, in no way responsible for it.

But I think when you do a scientific paper of any kind, it is common to ask your peers and colleagues to look it over, give you suggestions. I have received a lot of suggestions, made a lot of changes, and so forth.

Senator PRESSLER. Your study includes graphics of several system options and some excellent charts.

What are your estimates of the ultimate cost of systems that may be derived from the SDI? Do you have any estimations of cost?

Mr. CARTER. No, I did not include any cost estimates in here, and I did not do so for a good reason. It is hard enough to draw in your mind, as I did for this paper, a hypothetical future defense system, estimating the kinds of technologies that might be involved in it. It is much harder to gage the cost of it.

I did not make such an attempt, thinking that the best available cost numbers are unreliable. I did not repeat some of the calculations that have been made. But I can tell you how others have attempted to make such calculations.

On the whole, when relatively precise estimates of costs are made, not just several hundred billion dollars or something, but when someone comes to you, as several have done, with estimates ranging from $50 billion to a couple hundred billion dollars, what is typically done in those cases is to estimate the total on-orbit weight required by the technology used. For instance, if you are using a hydrogen flucride laser and you know how much of the reagents that are used to make the chemical reaction that fuels the laser, how much of those chemicals you need, you know what today's launch costs are, and maybe you discount them a little bit for the future, and you say how much does it cost to put all that stuff up in orbit. You calculate that number, then you multiply it by 1½ or 2 or something on the assumption that you not only have to put up the chemicals, but you also have to put up the laser and the sensors and so forth. That kind of on-orbit weight calculation is typically the basis for cost estimates that are made. And there is nothing dishonest about that process. It just is not a very reliable guide. So I deliberately did not do those kind of calculations.

Senator PRESSLER. In your view—based on the study—would the deployment of space-based or space-directed defenses increase U.S. security? If so, why? If not, why not?

We had an argument represented here this morning that it would increase our security; therefore, we should pursue strategic defense. The last panel indicated it probably would not increase our security.

What is your view?

Mr. SHARFMAN. Well, of course, you always have to say compared to what. If you want to compare it——

Senator PRESSLER. Well, compared to doing nothing, let's say.

Mr. SHARFMAN. Compared to doing nothing, a great deal depends on the effectiveness of whatever system we were able to develop and to deploy. Also since our security has to do in part with the state of mind we induce in the Soviet leadership, that is to say, deterrence, it would depend somewhat on how the Russians evaluated our system. Moreover, one of your earlier witnesses mentioned, and I would certainly agree, that if we do this, the Russians will try to do something as well. Especially since a treaty exists, it is inconceivable to me that they would let us deploy a defensive system without attempting to deploy their own. Therefore, we would want to ask whether the effect of the Soviet system would be to increase our security or not, and that would depend on our estimate of how good it was, and perhaps our estimate of the Russians' estimate of how good it was.

Trying to sort all this out, it seems to me that there are three different worlds to envisage. One is a world in which defensive systems are very good indeed. A witness this morning spoke of a five-layer system which he calculated as being 99.99 percent effective. Well, a system like that, but for the fact that it is almost certainly impossible, at least within any of our lifetimes, might well increase our security.

A second kind of regime to consider is a system that is largely ineffective, perhaps one in which each layer might shoot down 10 percent of the missiles that were fired at it, and a system like that would be unlikely to change significantly the existing balance of terror; it would simply involve spending a tremendous amount of additional money.

The middle ground—the effects of a system that had a more than trivial capability but still was a long way from being perfect—has to be looked at in terms of some hypothetical examples. That is, you cannot assess it on a prior basis. You have to say, well, let's imagine this and track through how it would affect our security. Let's imagine that and track through how it would affect our security, and so forth. That is something that we hope to do in the larger assessment which you, among others, requested that we do. But it is not something that we have done now, and to my knowledge, it is not something that anybody has done now.

Senator PRESSLER. Dr. Carter, did your calculations indicate that in most instances it would be cheaper to counter a defensive network than to build a defensive network? Would you agree with this statement?

Mr. CARTER. Yes, that is the way it looks. If you take at face value the kind of technologies that, for instance, Jim Fletcher and his group in the Defense Department this summer looked at; you say let's pretend that we could build such a thing and deployed it; you ask what does the defense look like compared to the offense

that is needed to saturate that defense, and you just compare them. And that is what that table tries to do over there.

Now, that is a dicey business, and one should not take all of this to the third significant digit, but for all of the technologies that we have looked at, that our Government has looked at, and that people have looked at outside the Government, when you make that kind of comparison it does look like the cost of the defense needed to counter a growing offense is comparable to or larger than the cost of the offense it is supposed to counter. That obviously bodes ill for a defensive initiative, a spending race between offense and defense, and clearly what the present strategic defense initiative in that case will have to do is either use different technologies or do better.

But that is the way it looks now. Remember, we are looking at technologies that we really do not understand very well in detail. So these comparisons are heuristic only. But the heuristic comparisons do not look good for the defense. That is as much as one can say right now.

Mr. SHARFMAN. I might add just the point that this table envisages a four-layer defense. You have heard testimony this morning that perhaps a five-layer defense would be necessary. Each layer, of course, increases the cost to the defense of making improvements in response to offensive countermeasures.

Mr. CARTER. Let me give an example, if I may, of why that turns out to be—how these comparisons are made, very crudely. We had an example of an orbiting X-ray laser system which you saw there on the board, and that 10 satellites in orbit for every 1 over the Soviet Union on duty doing the job. And each of those lasers, each of those laser battle stations could attack some 10 Soviet boosters.

Now, that means every time the Soviets deploy 10 boosters in their country, you need to put 1 X-ray laser overhead, and as you put 1 X-ray laser overhead, you have to put 10 around the globe. That means every time they deploy 10 boosters, you deploy and put up in space and maintain on orbit 10 X-ray lasers. Well, there is some kind of symmetry here, so you think to yourself, who is going to win that race?

Well, they both involve a space launch, they both involve the cost of a booster. We have to build—our battle station might be rather more complex than 10 reentry vehicles. We have to keep it on orbit, maintain it on orbit year in and year out. They get to maintain theirs in their silo where they can fix it and so forth. So it looks like every time they build a rocket we have to launch a rocket and keep something on orbit. That looks like a loser.

Now, whether one can say more than that, that it looks like a loser, I don't know, but that is the kind of comparison that is being made, both in our report and within the Government.

Senator PRESSLER. Though your research did not focus on this issue, if you were asked today is the Soviet Union or the United States further ahead in the arms race in space, what would your answer be?

Mr. CARTER. I would try to clarify the nature of that question rather than give an answer to that. I think that we are constantly comparing where we stand with respect to them. As it stands at the moment, neither of us has very much in the way of an active

military presence in space, apart from use of space for military support.

Our uses are small, they are very different. They do seem likely to grow dramatically in coming years but in ways we don't understand. And so really, it is an apples and oranges comparison. In a way it is difficult to make such a comparison unless I know what you are getting at, how you want to use that information. Then I could focus such a comparison.

But across the board, I know everyone is trying to make such comparisons, and I find them, unless I know the end use of them, very difficult to interpret or make sense of. So I would rather not say unless I knew why.

Mr. SHARFMAN. I would make one more comment in regard to that. You recall that when Dr. Carter was explaining the methods by which he carried out the study, he pointed out that a large part of his research consisted of going to the laboratories and talking to the scientists who were doing the work in order to get some sense of where they were going and how fast they were getting there.

We are not in a position to conduct similar interviews with Soviet scientists. We do have some intelligence information, but there is an awful lot more conjecture and guesswork in information about Soviet research and development programs than there is about our own research and development programs, and this morning's administration witnesses were the first to admit that there is a lot of uncertainty about the present state of our own research and development program.

Senator PRESSLER. I do not know if Dr. DeLauer made it to this hearing.

Is he here this afternoon?

We asked this morning that the Defense Department check to see if we could have him here this afternoon. I do not see him.

Let me ask the panel this question. Do you agree with Dr. DeLauer's view that deployment of BMD based upon futuristic technologies represents an effort on the scale of eight Apollo programs?

Mr. CARTER. I would say two things about that. If what Dick DeLauer meant when he said that was that it is a big effort, I certainly agree with that. The number eight I do not know about. I disagree with the kind of comparison that compares this effort to an Apollo program or building the bomb or something. People frequently say that, look, we went to the Moon, we built the shuttle, we built the bomb. How can you say we cannot do star wars? By "Star Wars" I mean an excellent or near perfect defense.

It is very different competing with nature, which does not change her laws and does not change her behavior; you study that behavior and you learn to work around it. Doing that, which is what we did with the Apollo program or the bomb, is very different from competing with a hostile intelligence. A hostile intelligence changes the rules on you all the time, it makes it a harder problem, makes it a changing problem, and it makes it several problems because you don't know what the offense is going to do.

People frequently say, I think with some justice, think if the Moon were populated by a race of beings intent upon frustrating our effort, the Apollo program would have been quite a different business.

So I think a benign technology program competing against nature and a military effort competing against a reactive opponent are very different.

The second point is that when both the Manhattan project and the Moon landing program began, the basic idea of how we were going to go about it was in hand. It was a matter of implementing this basic idea. "Star Wars" is very different. We do not even know quite how we are going to go about it. All the ideas we think of, as the paper demonstrates, have something wrong with them. So we know we have been thinking, but we know we are not there yet. So we do not have anything to do yet. We do not know what it is we have to do.

That is very different from knowing what you have to do and setting out to do it.

Senator PRESSLER. I do have some additional questions from other Senators and from our staff here, and we will ask those for the record.

I want to thank you for an effort very well done. I also want to thank you for the fine job you did on the workshop I requested that you hold and that you held in January. I think that OTA is not used enough by the Congress. We thank you very much.

Before concluding, I do have one more item to put into the record. It is the overview from Space-Based Missile Defense, a report by the Union of Concerned Scientists.

[The information referred to follows:]

SPACE-BASED MISSILE DEFENSE

A Report by the Union of Concerned Scientists

"I call upon the scientific community who gave us nuclear weapons to turn their great talents to the cause of mankind and world peace: to give us the means of rendering these nuclear weapons impotent and obsolete."

President Reagan, March 23, 1983

Overview

These words unveiled the President's Strategic Defense Initiative, a "comprehensive and intensive effort" with the "ultimate goal of eliminating the threat posed by strategic nuclear missiles." It proposes to rely on unborn generations of sophisticated space weapons that the Secretary of Defense told "Meet the Press" would provide a "thoroughly reliable and total" defense. We shall adopt Mr. Weinberger's words, and refer to the President's goal as *total ballistic missile defense*, or *total BMD*—what in the vernacular is now called "Star Wars."

Every sane person yearns to escape from the specter of nuclear annihilation. But that consensus still leaves a host of unanswered questions: will these BMD systems, which still are just conceptual designs, provide a total defense of our civilization against the Soviet missile force? That force now carries 9000 nuclear warheads, each far more powerful than the Hiroshima bomb, and able to arrive on US targets within 30 minutes. (The US arsenal is, of course, equally devastating.) If these defenses of the distant future could protect us totally against today's threat, could they cope with the Soviet strategic weapons of their own era?

What would the Soviets' response be? Would they devote themselves to a similar effort, and agree to reduce their offensive nuclear forces? Or would they perceive this new American program as an attempt to nullify Soviet nuclear forces—as a supplement to the emerging capacity to destroy Soviet missiles in their silos? If so, would they not respond with a missile buildup and "countermeasures" to confound our defenses, so that they could still destroy the United States (just as the US can destroy the USSR)? Or would the Soviets not have this option, because our defense would be truly total—robust enough to foil any offensive countermove?

This report addresses these questions. It examines the proposed BMD systems in the light of the scientific facts and principles that will govern their performance, and with the aid of the information released to the press by the Administration's Defense Technologies Study Team headed by Dr. James C. Fletcher. There is general agreement that a defense of our population is impossible unless the vast majority of Soviet missiles can be intercepted in the first phase of their flight while their booster engines emit a brilliant flame and before their multiple warheads are released. We therefore devote the bulk of our attention to "boost phase" defense.

In assessing each BMD system, we first assume that it will perform as well as the constraints imposed by scientific law permit—that targets can be found instantly and that aiming is perfect, that the battle management software is never in error, that all mirrors are optically perfect, that lasers with the required power output will become available, etc. Above all, we first assume that the Soviets' forces remain static—that they do not build more missiles or install any countermeasures. Hence, our initial optimistic appraisal ignores the critical question of whether BMD will eventually work as well as it possibly could, and does not depend on classified information.

Even in this utopian regime, our findings concerning the proposed BMD schemes are that:

- Chemical laser "battle stations" in low orbits, or "space trucks" carrying "kill vehicles," will have to number in the thousands to give adequate coverage of the Soviet silo fields; simply lofting these stations into orbit would cost upwards of $70 billion.

- Excimer lasers on the ground, whose beams would be reflected towards boosters by over a thousand orbiting mirrors, would require power plants which alone would cost some $40 billion.

- The atmosphere and the earth's magnetic field combine to make particle beam weapons wholly implausible into the foreseeable future.

These cost estimates do not include research and development, or construction of space platforms, lasers, kill vehicles, mirrors, and command and control facilities. Just the R&D portion of this program has been described by Dr. Richard DeLauer, Under Secretary of Defense for Research and Engineering, as having at least eight components "every single one . . . equivalent to or greater than the Manhattan Project." Furthermore, all costs will climb rapidly should the mirrors be imperfect, the time for aiming exceed several seconds, redundancy be desired, etc. The full costs cannot even be estimated because the proposed technologies are still too immature, but it is clear that many hundreds of billions of dollars would be needed.

The proposal to launch x-ray lasers pumped by nuclear explosions at the time of an attack would require a new fleet of submarines, as there is no suitable base on land close enough to Soviet silos to allow interception in the time available. The laser's soft x-rays cannot penetrate the atmosphere, and they deliver a rather light blow from which the booster can readily be protected. These facts, when combined with the feasibility of shortening boost to 40 seconds, imply that the x-ray laser is not a viable BMD weapon.

The Soviets have made it clear that they view the quest for total BMD as an unacceptable threat. They fear that such a BMD system would give us the option to strike first—an understandable fear since Mr. Weinberger has said that he would view a similar Soviet system as "one of the most frightening prospects" imaginable. And they have heard the Administration officials speak of space-based BMD as a lever for stressing the USSR's technologically less sophisticated economy.

In the real world we must therefore expect a determined Soviet reaction unconstrained by all existing agreements, because the very testing of our defensive weapons would violate our obligations under the ratified ABM Treaty. The Soviet reaction is likely to include:

- Offensive missiles designed to circumvent BMD, such as submarine-launched cruise missiles that cannot be intercepted from space.

- Fitting ICBMs with more powerful engines so that the boosters would burn out quickly and inside the atmosphere, which would stress any BMD system, and eliminate interception by kill vehicles and x-ray lasers.

- Cheap decoy ICBMs—boosters without warheads in fake silos—to overwhelm boost phase interceptors.

- Weapons that would exploit the fact that even a battleship's armor could not protect a space station from quite primitive types of attack.

- A Pandora's box of largely developed countermeasures that would make targeting of boosters and warheads exceedingly difficult.

All these countermeasures would exploit off-the-shelf weapons and techniques that exist today, in contrast to the unproven and improbable technologies on which our proposed defenses would rely. Hence, the Soviet response will be cheaper and far more reliable than our defenses, and available as those defenses emerge.

While this quest for a total defense against nuclear missiles would be endless, the decision to embark would have immediate political repercussions. Indeed, the first repercussion has already been heard: the US rebuff to Soviet overtures to negotiate constraints on anti-satellite (ASAT) weapons—a stance dictated by the plans for a space-based BMD system. The ABM Treaty could not survive the start of this endless journey, and with it all constraints on offensive forces would go overboard. The impact on NATO would be profound. It would inflame existing suspicion that the US intends to conduct nuclear operations in Europe without risk to itself, and it would erode alliance cohesion because Europeans would hold the US responsible for exacerbating East-West tensions.

The risk to our survival would mount dramatically were we ever to begin erecting the BMD system. This budding system would be exceedingly vulnerable to attack. Nevertheless, its capabilities would be overvalued by our adversaries, and its installation could well be perceived as an attempt to disarm the Soviet Union. These circumstances could in themselves provoke open conflict.

If we get through this hazardous passage, will we have reached the promised land where nuclear weapons are "impotent and obsolete"? Obviously not. We would then have a defense of stupefying complexity, under the total control of a computer program whose proportions defy description, and whose performance will remain a deep mystery until the tragic moment when it would be called into action.

The President and his entourage occasionally argue that we must pursue this quest because the benefits of success outweigh the costs and risks. However, that is only an argument for a research program in strict conformity with the ABM Treaty. Such a program has always had our support. It is needed to protect us from Soviet surprises, and it might uncover concepts that could actually provide a viable defense. But there is an enormous gulf between such a program and a call from the ramparts for a national "experiment" to mount a defense based on untried technologies and provocative doctrines. We have delineated the costs and risks of such an "experiment." At best, the outcome would be a defense of precarious reliability, confronted by offensive nuclear forces designed to circumvent and overwhelm it, and a host of new "anti-BMD" weapons to attack our armada of space platforms which, in turn, would have to be defended by yet another fleet of anti-anti-BMD weapons.

It is difficult to imagine a more hazardous confrontation. And it is equally difficult to understand how anyone can believe that this is the path towards a less dangerous world. A direct and safe road is there for all to see—equitable and verifiable deep cuts in strategic offensive forces and immediate negotiations to ban all space weapons. If we are to take that road, we must abandon the misconception that nuclear explosives are military weapons, and the illusion that ever more sophisticated technology can, by itself, remove the perils that science and technology have created. We must, instead, recognize the overriding reality of the nuclear age—that we cannot regain safety by cleverly sawing off the thin, dry branch on which the Soviets are perched, for we cling to the same branch.

Study Panel

Kurt Gottfried, Panel Co-chair; member, Board of Directors, Union of Concerned Scientists, Professor of Physics and Nuclear Studies, Cornell University, former Chairman, Division of Particles and Fields, American Physical Society

Henry W. Kendall, Panel Co-chair, Chairman, Board of Directors, Union of Concerned Scientists; Professor of Physics, Massachusetts Institute of Technology

Hans A. Bethe, Professor of Physics Emeritus, Cornell University; Nobel Laureate in Physics; Chief, Theoretical Division, Manhattan Project; member, President's Science Advisory Committee (1957–60); Strategic Military Panel (1957–69)

Peter A. Clausen, Senior Arms Analyst, Union of Concerned Scientists; Fellow, Woodrow Wilson International Center for Scholars; former political analyst, Department of Energy and Central Intelligence Agency

Richard L. Garwin, IBM Fellow at the Thomas J. Watson Research Center; member, President's Science Advisory Committee (1962–65 and 1969–72); member, Defense Science Board (1966–69)

Noel Gayler (Admiral, USN, Ret.), former Commander-in-Chief, U.S. Forces in the Pacific; former Director, National Security Agency; former Assistant Chief of Naval Operations (Research and Development)

Richard Ned Lebow, Professor of Government and Director, Peace Studies Program, Cornell University; former Professor of Strategy, National War College, Scholar-in-Residence, Central Intelligence Agency

Carl Sagan, Professor of Astronomy and Space Sciences and Director, Laboratory for Planetary Studies, Cornell University

Victor Weisskopf, Institute Professor Emeritus, Massachusetts Institute of Technology; former Director-General, European Organization for Nuclear Research (CERN), Geneva; former President, American Physical Society

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Senator PRESSLER. Does minority or majority staff have any further business that I have overlooked?

[No response]

Senator PRESSLER. With that, I call this hearing to a close.

Thank you very much.

[Additional questions and answers follow:]

DR. DRELL'S RESPONSES TO ADDITIONAL QUESTIONS SUBMITTED BY SENATOR PRESSLER

Question 1. Do you believe that the SDI is a prudent hedge against Soviet ABM breakthrough or breakout?

Answer. Not as I understand what is being proposed. A well coordinated and directed research and technology program at the level of (very roughly) 1 to 2 billion a year is a prudent hedge against a Soviet ABM breakthrough or breakout. The SDI goes beyond this calling for an expansion to a spending total of 26B for the next 5 years in order to demonstrate technology toward a Presidentially directed goal of rendering nuclear weapons "impotent and obsolete". My concern as expressed in my testimony, is that this will be seen—and become a unilateral change in the basis of the United States-Soviet strategic relationship. A political foundation should be built through dialogue with the Soviets before any such major change is implemented as I discussed.

Question 2. In your view, could the SDI lead the Soviets to accelerate their BMD efforts?

Answer. Yes. Lacking the proper political framework, we are also likely to see a further buildup of offensive forces in order to preserve the deterrent in the face of growing defense capabilities—real or perceived.

Question 3. What is your assessment of the Administration's March 31, 1984 ASAT report? Do you believe that the Administration uses a reasonable standard for verification in its assertion that an ASAT ban is unverifiable?

Answer. As I testified I disagree with its conclusion that it would not be "productive to engage in formal international negotiations" on ASAT arms control at this time. I believe we can verify appropriate bans on ASAT tests as well as dismantling of launch facilities. On the other hand a ban on existence of all ASAT's would be difficult to verify. However a ban now on testing would prevent the Soviets from developing an effective ASAT capability against important U.S. systems. There are also important unilateral steps that should be taken by the United States, as I testified, to improve our satellite system survivability.

Question 4. Do you believe that a ban on dedicated ASATs, such as the Soviet SS-9 interceptor, and strict limitations on other systems with possible ASAT capabilities, such as high powered lasers and the Gallosh ABM, can be effectively verified?

Answer. Yes—to a degree of effectiveness appropriate to meet U.S. security needs.

Question 5. Do you believe that the Soviet ASAT poses a serious threat to U.S. security? Could the United States prudently forego ASAT flight tests for a brief period in order to test Soviet seriousness on ASAT negotiations?

Answer. I do not believe the current Soviet ASAT poses a serious threat to U.S. security for two reasons: its low reliability and the very limited orbital paths and low altitudes against which it can operate. Yes, the United States could prudently forego ASAT flight tests for a brief period.

Question 6. If the United States were to continue ASAT flight tests could this add to the difficulty of reaching a verifiable ban on dedicated ASAT's?

Answer. The United States could continue ASAT flight tests for a while before adding significantly to the difficulty of reaching a verifiable ban on dedicated ASAT's. Eventually, however, once the United States has completed tests on its ASAT now under development and has reached a capability for deployment of an effective system, the difficulty will be greater—especially since by then the Soviets will, presumably, have continued testing and also improved their system.

OTA'S RESPONSES TO ADDITIONAL QUESTIONS SUBMITTED BY SENATOR PRESSLER

Question 1. If total defense against nuclear attack is impossible, what other objectives might be served by the SDI? Are these other goals worth the huge expense and effort?

Answer. The background paper identifies and discusses six such goals: (1) stengthen deterrence by preventing pre-emptive destruction of retaliatory forces; (2) strengthen deterrence by preventing the use of nuclear weapons as decisive military tools for high-confidence "limited" strikes on conventional forces; (3) save lives in

the event of a war; (4) shape the course of arms competition and arms control, by obliging the Soviets to alter their present patterns of weapons deployment; (5) respond to Soviet BMD efforts; and (6) protect against accidental missile launches and attack from other nuclear powers. While each of these goals is important, it is not clear that the SDI would necessarily accomplish any of them.

OTA's larger study, which began last month in response to your request, will attempt to assess the likelihood of attaining these goals and their significance compared to each other and to the costs of various kinds and sizes of "less than perfect" defense.

Question 2. Does the United States require the SDI to keep pace with Soviet BMD programs?

Answer. No. Before the SDI began, the United States had an extensive program of BMD research, one of whose purpose was to avert the risk of a Soviet breakout by ensuring that our technology was keeping pace or staying ahead of theirs.

Question 3. Do you believe that the SDI will increase stability or might it accelerate the pace of Soviet BMD programs?

Answer. The SDI, as a research program, might or might not contribute to stability, depending on how the Soviets reacted. Some people believe that it might disrupt existing Soviet plans for military modernization, and thereby contribute to U.S. security, if not to stability. On the other hand, it would certainly provide the Soviets with a reason to accelerate their own BMD programs, and an excuse to withdraw from the ABM Treaty if they so desire. We are not in a position to judge how the Soviets would actually react if the SDI programs are funded and move ahead.

If and when research under the SDI led to testing, this would violate the existing ABM Treaty. This would presumably be destabilizing unless it proved possible to work out with the Soviets a modification of the treaty that permitted such testing without jeopardizing the objectives of the treaty. This would be, at best, a severe challenge to U.S. diplomacy.

If and when the SDI led to deployments, its impacts on stability would be very complex. This is an issue we will address in some depth in the larger study you have requested.

Department of Defense Comments on OTA's Background Paper on "Directed Energy Missile Defense in Space," May 8, 1984

Statement by Lt. Gen. James A. Abrahamson, Jr.

On April 24, 1984 the Senate Foreign Relations Subcommittee on Arms Control, Oceans, International Operations, and Environment released a background paper prepared by Ashton Carter under the auspices of the Office of Technology Assessment. Although the press has described the report as critical of the Strategic Defense Initiative, the paper actually addresses neither the goals nor the merits of the SDI research program. Furthermore, independent authorities have found that the paper contains technical errors, unsubstantiated assumptions, and conclusions that are inconsistent with the analysis in the body of the report.

It is basic to any assessment of the Strategic Defense Initiative to evaluate it as a research program exploring technologies that are not intended to be exploited for many years. Yet the paper challenges the SDI based on the capability of current defense technologies to counter offensive capabilities that are at least 20 years in the future. It also misleads the reader concerning the goals of the current research program, which are to provide future leaders with options for decisions they may have to make to strengthen deterrence with effective strategic defenses.

While the body of the report repeatedly stresses the importance of a vigorous research and technology program as a hedge against unilateral Soviet exploitation of new technologies, the conclusions do not address the consequences of current and possible future Soviet efforts. It fails to consider the conclusions of the large body of national security experts who have studied the strategic implications of the SDI and judged that it can have great promise for strengthening deterrence and enhancing stability.

Technical Review of Ashton Carter's Background Paper "Directed Energy Missile Defense in Space"

The background paper by Ashton Carter entitled "Directed Energy Missile Defense in Space" was released on April 24, 1984. The report has been used by some opposed to efforts to explore and develop possibilities for effective ballistic missile defenses to attack the Strategic Defense Initiative (SDI). This summary was pre-

pared based on reviews of the Carter paper conducted by those organizations and many individuals whom Mr. Carter consulted in preparing his report.

This summary covers both areas where the report has made significant errors and also where there is substantive difference of opinion among the experts. The reviewers agreed that errors were present in the report but different individuals had varying opinions on the seriousness of these errors. However, all individuals, including Mr. Carter, in conversations with the SDI staff agree on the need for a focused research and technology program. Although Mr. Carter has indicated that his report does not relate to the SDI nor judge the merits of that program, it does state in the introduction that the paper deals with a "long-term research and development—Star Wars" program.

This summary intended to note some of the fundamental errors and misinterpretation of data inherent in the report.

BOOSTER CHARACTERISTICS

The report stresses that new ballistic missile threats constructed as a Soviet or other nation's response to a US defensive system might look considerably different. Much attention is given to the possibility that the Soviets could develop a "fast-burn" booster which would finish its boost phase while still within the outer reaches of the Earth's atmosphere. It is true that such fast burn boosters are technically credible and could defeat or complicate the task of boost-phase intercept. Those who reviewed Mr. Carter's paper make three key points about fast burn boosters. First, it will be well into the first decade of the next century before the Soviets could develop and deploy, at significant cost, a large fraction of their reentry vehicles onto such boosters. Second, the fast burn boosters would result in significantly reduced payloads, less warheads, have less accuracy, and be less capable of countermeasuring against later phases of the ballistic missile defense. The reduction of 70–90 percent in total RV payload and greatly reduced decoy payload is equivalent to a 70–90 percent effective boost-phase defense against current boosters! This means that a fast-burn booster attack could be adequately handled by the midcourse and terminal phases. Thus, forcing the Soviets to go to fast burn boosters is the same as deploying a highly effective boost-phase system. Third, there are a number of new technologies with considerable potential against fast-burn boosters. The SDI is designed to fully investigate these technologies.

BOOST-PHASE TECHNOLOGIES

The report provides an excellent review of how various technologies work, however, it does not do a satisfactory job in explaining how they might be employed.

The analysis of the number of laser platforms needed to destroy a given number of boosters is seriously in error. The choice of laser weapon parameters is such that the result is an extremely short lethal range. This error causes the number of laser weapons to be so large as to raise questions on the practicality of this approach. The fact is that the weapon parameters would be optimized to result in the minimum number of weapons necessary to provide the coverage and target handling capability required.

The report's analysis of ground-based lasers used in a relay mode both misstates current technology capabilities and uses inappropriately pessimistic input numbers. Although is it acknowledged that "impulse-kill" lasers can destroy boosters via a different mechanism than thermal lasers, it does not acknowledge that recent advances in the free-electron and excimer lasers may make this possible. Further, the report fails to acknowledge that considerably lower power levels are required to effect this kill mechanism. The arbitrary, but poor, choice of parameters for a ground-based laser/space relay mirror system results in a system which is at least an order of magnitude worse than optimum. Thus, the report's failure to consider efficient systems based on known technology could result in erroneous or misleading conclusions.

The analysis of the X-ray laser concept is also flawed. Although the progress and status of concept development in this area is highly classified, there are features of such systems which make them both applicable over much longer ranges and capable of attacking targets much deeper in the atmosphere than stated. When these errors are corrected the X-ray laser concept shows great potential.

For neutral particle beams the comments on accelerator status and ultimate beam divergence are wrong, as is their estimate of how deep these devices can penetrate into the atmosphere. Contrary to the statements in the report, neutral particle beams with achievable beam energies can penetrate any conceivable ballistic missile target. When these errors are corrected, a very modest constellation of such devices

could negate most ballistic missile threats. This technology is advancing very rapidly and is comparable to laser technologies in promise. The skepticism concerning the feasibility of charged particle beam devices in space, as opposed to the neutral particle beams, does not consider new and innovative applications and is based on information which is very much out of date.

The assessments of the feasibility of space-based kinetic kill vehicles is based on the same mistakes made in analyzing the laser weapons. The research and technology objectives of the SDI program are focused on developing considerably smaller interceptor weights than assumed in the report. When these errors are corrected the number of systems required is 4-5 times less than reflected in the report. Moreover, total orbital weights become modest and well within current and anticipated US launch capabilities. Furthermore, contrary to assertions in the report, "electromagnetic guns" show great promise in increasing interceptor velocities so that kinetic intercepts can be accomplished even against "fast-burn" boosters.

OTHER ELEMENTS OF BOOST PHASE DEFENSES

The report correctly stresses the importance of surveillance, acquisition, pointing and tracking, battle management and communications and control systems. The SDI has been formulated to focus and emphasize research on these elements. Indeed, over one half of the total SDI resources will be devoted to technologies in those areas. However, experts in each area do not concur with the report's pessimism on the potential for solving the technical issues in each area.

COUNTERMEASURES

The issue of defensive systems and their vulnerability to passive and active countermeasures is a crucial one. The statement that "vulnerability of these satellites is a cardinal concern because . . . they are impractical to harden, conceal, or proliferate to any significant degree" is not correct. Although it is true that very little has been done in the past to reduce the vulnerability of space systems, technologies and techniques have been identified that will insure survivability. Although there are many potential threats to space-based assets, we believe that space assets can be made survivable. To provide just one example, Mr. Carter proposes that pop-up X-ray lasers would be extremely effective against satellites. However, there are also statements in the report that a suitably constructed shield could defend ballistic missiles against X-ray lasers. The application of this shielding technique is more practical for satellites and spacecraft than for ICBMs!

With regards to other suggested countermeasures reviewers have made two comments. First, many of the countermeasures, such as fast burn boosters are as effective in enhancing possibilities for intercept in midcourse and terminal phases as a highly effective boost phase intercept system might be. Second, the Fletcher panel has identified ways to counter every countermeasure the offense may choose to make. Whether these defensive measures are cost-effective or technically feasible is a major research objective of the SDI. To provide just one example, the proposed "booster decoys" which would proliferate targets for a boost phase defense are neither cost effective nor likely. The primary cost for an ICBM is the booster and silo, not the precision guidance and warheads. A plausible decoy would therefore be nearly as costly as real boosters, and thus an unappealing countermeasure.

HYPOTHETICAL SYSTEM ARCHITECTURES

The proposed "system" discussed in the report is poorly conceived. As already mentioned the number os space-based weapons systems discussed is wrong by factors of from 5-10. Thus, it is projected that a few hundred lasers or less could "handle" the entire attack without resorting to X-ray lasers at all. Similarly the number of required sensor platforms is in error. The report contains two fundamental errors in sizing the midcourse intercept system. First, the midcourse interceptors could be constructed so that only one launch site could cover the entire United States, rather than the two assumed in the report. Second, the Fletcher study concluded that effective discrimination of decoys from warheads could be accomplished in midcourse. These result in more than a factor of ten error in midcourse interceptor required. Even greater errors were made in the number of terminal interceptors required. These errors resulted in a gross overestimate in the required number of terminal interceptors and associated radars.

SUMMARY

The SDI leadership and those who worked on the studies which defined the SDI are aware that the technical challenges which must be met on the path to achieving the President's dream are considerable. The view expressed in the report that the problems are nearly insurmountable is not supported by the technical data, nor by the technical experts most familiar with the technologies involved. The SDI has been expressly formulated to address the many very real issues. To succeed, the SDI needs the full support and involvement of the scientific and technical community. Together, we may be able to turn the President's dream of hope for a safer future into a reality.

OTA's Response to General Abrahamson's Comments on Background Paper Entitled "Directed Energy Missile Defense in Space," May 17, 1984

On May 8, 1984, Lieutenant General James A. Abrahamson, Jr. commented to the press on OTA's Background Paper entitled "Directed Energy Missile Defense in Space" (see "Department of Defense Comments on Directed Energy Missile Defense in Space"). General Abrahamson addressed several technical areas where his information seemed to differ from OTA's. This note reaffirms the correctness of the technical information in OTA's Background Paper on which General Abrahamson commented, explaining each point.

This note first treats the specific comments raised by General Abrahamson and then turns to some general comments on interpretations of the Paper made by various parties.

SPECIFIC COMMENTS

Booster Characteristics

1. Fast-burn boost requires nothing like a 70-90 percent reduction in ICBM payload. It is not necessary to turn to single-warhead missiles in order to have fast booster burn. Both highly MIRVed (MX-scale) and single warhead (Midgetman-scale) fast burn boosters were designed in Defense Department studies. These missiles are only slightly larger than their slower-burning counterparts, MX and Midgetman, yet they carry the same payload. Note that the hypothetical defensive system architecture described in section 7 of the Background Paper was designed to counter a future Soviet booster similar to the MX Peacekeeper, not a fast burn MIRVed booster (the MX burns faster than the Soviet SS-18 but much slower than the hypothetical fast burn boosters envisaged as countermeasures).

2. Fast burn does not require sacrificing precise warhead accuracy. Precision deployment is possible above 90 kilometers. Fast-burn missiles can be silo killers.

Note also that to destroy U.S. cities, as opposed to U.S. silos, Soviet missiles need not have precision accuracy.

3. Fast-burn boosters can carry decoys and other penetration aids for evading midcourse and terminal defense layers. However, the short deployment time and atmospheric drag at low altitudes might make deployment of penetration aids from fast-burn boosters more difficult than from today's missiles. This possibility is a legitimate point in favor of boost phase defense and was noted on page 56 of the Background Paper and repeated on page 59.

Boost Phase Technologies

1. We recognize that there is some variation among workers in this field in their estimates of how many satellites carrying weapons of a given kind (20 MW chemical lasers with 10 m mirrors, in the first example in the Background Paper) would be required on orbit to achieve a given level of defensive capability. These variations in constellation size and absentee ratio can be as much as a factor of two or three, but not five to ten as General Abrahamson seems to imply elsewhere. These variations are not large enough to affect conclusions, especially since many other uncertainties in these calculations are at least as large. Our estimates lie between the Fletcher Panel's estimates and those of the Union of Concerned Scientists, though much closer to those of the Fletcher Panel, and we consider them to be reasonable estimates.

Factors affecting constellation size estimates include: (1) geography of offensive missile deployment; (2) the fact that required weapon dwell time varies depending upon the position of the satellite with respect to its target; (3) the coverage of the constellation fluctuates in time, so that the protection afforded by a given number of defensive satellites varies around some average, dipping periodically to a "worst

case" where satellites involved in the engagement are on average farther from their target. (Of course, the Soviets could calculate, for any deployment, when this worst case would recur.)

2. The Background Paper does not mention that power levels for impulse kill are smaller than for thermal kill because it is pulse energy and pulse repetition frequency, not average power, that is the measure of merit relevant for impulse kill.

3. We have reviewed our estimates of parameters for a thermal kill ground-based laser system and have found no error; General Abrahamson does not explain where his estimates differ.

4. With respect to the X-ray laser, General Abrahamson seems to be referring to certain ideas (still classified) for making a somewhat new type of X-ray laser. The author is fully aware of these ideas, but they remain only untested concepts, and they are different from the much-publicized Excalibur device under investigation at the Lawrence Livermore Laboratory. The Background Paper's discussion of Excalibur is correct.

5. The Background Paper correctly cites the beam divergence associated with gas cell stripping to form a neutral particle beam. It is true, as General Abrahamson points out, that other methods of removing the extra electrons from negative ions might *ultimately* reduce the beam divergence introduced by stripping.

6. The Background Paper's estimates of the altitude to which the neutral particle beam can penetrate are based on calculations of the interaction of the beam with the air and on realistic engagement geometry. It is possible that in his own estimate, General Abrahamson calculated the depth to which the beam would penetrate if fired straight down. However, in order for each weapons satellite to have a reasonable radius of coverage, the line of fire must be on average far from vertical, meaning the beam must pass through more air to reach a given altitude.

7. "New and innovative" applications of charged particle beams are treated explicitly on page 31 of the Background Paper. The author is fully aware of related efforts at the national laboratories.

8. The Background Paper shows clearly that a guided projectile weighing less than 15 kilograms had better be a "research and technical objective of the SDI," since otherwise the on-orbit weight of a rocket-propelled system would be too large, as General Abrahamson states. We chose 15 kilograms advisedly, taking into account the fact that the guided projectile must have sizable terminal divert motors in addition to sensors and electronics. Interceptor weight is roughly proportional to projectile weight for constant velocity gained.

9. The Background Paper does not assert that electromagnetic guns will not work, but it does point out that the projectile energies are substantial. This energy must be supplied from on-orbit sources.

Other Element of Boost Phase Defense

No comment.

Countermeasures

1. Battle stations deployed in low earth orbit would be impractical to conceal over long periods from future sensors. The author believes that no one familiar with space surveillance (from space and from earth) will contradict this statement.

2. Battle stations are impractical to proliferate unless they are at least several times cheaper than the means to destroy them. This is true because the offense must only "cut a hole"—containing of order a tenth of the satellites—in the defense constellation.

3. General Abrahamson's analogy between battle station hardening and booster hardening is superficial: one must compare not only the shields surrounding these objects, but the circumstances under which they would be used and the economics of their respective missions. There are three major differences:

Timing.—The offense/ASAT attacker can afford tens of seconds—maybe minutes—of dwell time, and repeated attack, to burn through satellite shielding. If a booster shield only succeeds in prolonging lethal dwell times to several seconds, by contrast, it forces the defense to large increases in battle station number in order to handle all the boosters in the few hundred seconds of booster burn time. In addition, defensive satellites must be shielded at all times, yet ready to sense, communicate, and shoot at a moment's notice.

Geography and Geometry.—The entire defensive satellite must be hardened to attack from all directions: from space or from the ground. Only the upper stages of boosters must be hardened against directed energy weapons that do not penetrate the atmosphere. Most crucially, defensive satellites can be attacked from the Soviet

Union. How, for example, will satellite shields hold up against repeated large impulse-killing pulses from the ground-based excimer and free-electron lasers General Abrahamson mentions?

Economics.—If the offense hardens just some of its boosters, but does not reveal just which ones are hardened in which way, the defense faces a choice: either it can assume all are hardened and beef up the defense accordingly (e.g., adding more battle stations, since dwell times must be longer to penetrate shielding; or doubling the number of X-ray lasers, so a first burst of X-rays destroys the shield and a second destroys the booster); or it can leave the defense as is, allowing the shielded boosters to penetrate unharmed. Just the opposite cost-exchange picture holds for satellite shielding. The offense need only threaten those satellites over its silo fields at the moment of attack; the defense needs to harden the entire constellation of defense satellites.

4. Decoy boosters do not need warheads, guidance systems, or upper stages (most of the cost of the booster). Moreover, they do not need protective silos, since they can be defended (by a less-than-perfect defense) against first strike. Or they can be used in a first strike.

Hypothetical System Achitecture

1. To meet midcourse interceptor size and cost goals, and to avoid basing the defense outside the continental United States, at least two midcourse launch sites would be needed to cover all ICBM approaches. Still more sites would be needed to cover all SLBM approaches.

2. The Fletcher study did not conclude that "effective discrimination of decoys from warheads could be accomplished in mid course." Nor could it. The Fletcher study did examine some interesting (though not decisive) ideas for improving the prospects for midcourse discrimination. These ideas are discussed in section 6 of the Background Paper. In consideration of these ideas, the Background Paper permitted only ten midcourse decoys per RV, rather than many more, to fool the midcourse sensors.

3. The Background Paper's estimates of terminal interceptor numbers are proper, though the author recognizes that, since the terminal system is not yet completely defined, differences among analysts of a factor of two (factor 1.5 in coverage radius), though not more, are possible.

GENERAL COMMENTS

OTA and the author realize that the circumstances of release of the Background Paper precluded the SDI program staff from reviewing the Background Paper before responding to Congressional inquires. We therefore greet General Abrahamson's comments in the spirit of open technological discussion which the SDI should welcome.

OTA and the author reaffirm the technical correctness of the Background Paper, including issues raised by General Abrahamson. We also note favorable reviews the Background Paper has received from Government laboratories and contractors, to which General Abrahamson referred.

The Background Paper stresses a fundamental distinction between useful but less-than-perfect defenses, on the one hand, and defenses so good that the Soviet Union simply could not destroy our society with nuclear weapons, on the other. Insofar as the SDI aims at a perfect defense, the Background Paper casts doubt upon how realistic the program is. With respect to less-than-perfect defense, and with respect to ballistic missile defense in general, the Background Paper makes no judgments; it is at that point intended to be a technical primer on boost phase intercept technologies. The Background Paper does not say that boost phase defense will not work at all, nor that less-than-perfect defenses are undesirable.

The Background Paper does not address the SDI as a research program. Virtually everyone agrees that some R&D is desirable, but the Background Paper does not address the scale, structure, or management of the R&D program, nor whether all of its sub-elements compete favorably with other defense R&D needs.

APPENDIX

WASHINGTON, D.C., *April 25, 1984.*

Senator LARRY PRESSLER,
Chairman, Subcommittee on Arms Control, Oceans, International Operations and Environment, Senate Foreign Relations Committee, U.S. Senate, Washington, D.C.

DEAR SENATOR PRESSLER: Enclosed is a statement of the results of the symposium held at the Peace Palace, The Hague, The Netherlands on

CONDITIONS ESSENTIAL FOR MAINTAINING OUTER SPACE FOR PEACEFUL USES

The symposium was sponsored by the United Nations University and the International Institute of Space Law and was really a workshop of some 30 international experts giving legal attention to all potential harmful influences that could damage or destroy the space environment, including but not confined to the military role in space.

Ambassador Buchheim, who testified at your hearing on "Arms Control and the Militarization of Space" was one of the participants. The Soviet Union sent a representative at the decisionmaking level, one who had participated in the Vienna antisatellite negotiations.

I anticipated that we would be able to conclude only optional proposals based on different assumptions concerning the role of the military in outer space, but finally we were successful in agreeing on a consensus statement. This was ready in time for presentation at the session in Geneva of the Legal Subcommittee of the UN Committee on the Peaceful Uses of Outer Space. And it is hoped that we can also be helpful to those who are negotiating in Geneva at the Conference on Disarmament. A future meeting is planned with a smaller number of participants.

One of the Judges of the International Court of Justice presided over the symposium, The Honorable Manfred Lachs.

Sincerely yours,

EILENE GALLOWAY.

CONDITIONS ESSENTIAL FOR MAINTAINING OUTER SPACE FOR PEACEFUL USES

Symposium organized by the International Institute of Space Law and the United Nations University in cooperation with the Palace and The Hague Carnegie Foundation.

THE HAGUE, MARCH 12–15, 1984

The participants in the Symposium agreed to the following summary of their work; it was understood that the United Nations University will publish the written contributions and an account of the discussions where the details of the analysis and proposals made by participants will be found. The list of participants is attached.

I. General conclusions

The basic common view shared by participants was a sense of risk and danger: the danger of an extension of the arms race into outer space and the risk of armed conflict in outer space; the direction of armament development might jeopardize existing international agreements designed to limit and control the military uses of outer space.

The symposium recalled the expressions of concern over current developments in international fora such as Unispace 82 and the United Nations General Assembly as well as by groups of concerned citizens in different parts of the world.

The meeting recognized the importance of renewed efforts at all relevant levels in developing the appropriate political climate and, at the same time, underlined the important role of international law in these efforts to safeguard outer space for peaceful uses.

In respect of legal measures designed to safeguard outer space for peaceful uses, the participants recalled the applicability of general international law, in particular the Charter of the United Nations and the body of law specifically dealing with outer space and emphasized the need to strengthen and supplement existing rules in response to new situations brought about by technological developments and changing circumstances. The meeting analyzed the proposals for new legal instruments submitted to the United Nations General Assembly and noted that these proposals were presented as drafts in the sense that they were negotiable.

Consequently, the meeting emphasized the urgent need to move towards actual negotiation, in good faith involving all concerned parties and, in particular, the two major space powers.

The objective of developing international agreement and international law for the purpose of maintaining outer space for peaceful uses should be seen in the larger context of working towards the creation of an appropriate legal environment for the future.

Within the framework of general international law, two special bodies of law are relevant: international law specifically related to disarmament and international law specifically governing outer space activities. Efforts in each of these areas should be mutually reinforcing.

In both scientific and legal terms outer space represents with land, sea and air the fourth realm of earth's environment. Within this general framework, the special body of law which has developed in response to the specific characteristics of outer space activities needs to be strengthened and developed. The meeting stressed the desirability of all countries becoming parties to existing treaties in this area. Further efforts should build on existing agreements and the preferred approach would be to supplement, as required, existing treaties by new legal instruments in appropriate form.

The urgency of new agreements had been expressed by the United National General Assembly in resolution 38/70 of 1983 concerning the prevention of an arms race in outer space: the Assembly had also requested the Conference on Disarmament to deal with this matter on a priority basis. In keeping with the primary role thus entrusted to the Conference on Disarmament, the meeting emphasized the urgent need for action by the Conference: in addition, the meeting pointed to the important role of other fora such as the Committee on the Peaceful Uses of Outer Space.

II. Specific issues and proposals

The symposium also discussed a number of specific issues and proposals which could assist in the task of elaborating new agreements designed to safeguard outer space for peaceful uses. In particular, the symposium wishes to draw attention to the following:

1. In terms of the method of approach consideration should be given to the advantages of focusing on activities in outer space by strengthening and extending the system of permitted, prohibited and desirable activities. In fact desirable activities in the form of international cooperation in outer space would be an important aspect of confidence building in this area.

2. While recognizing the obvious requirement of agreement by the two major space powers, participants stressed the importance of involving the international community of states so as to gain wide acceptance for new agreements. Also, while recognizing the value of unilateral declarations of intent, the meeting pointed to the importance of unilateral constraint by those countries possessing technological capability for outer space activities.

3. Participants felt that in the work on new legal texts designed to maintain outer space for peaceful uses, the control provisions in the Moon agreements would be a viable alternative for early inclusion in a separate agreement.

4. In relation to verification, the meeting discussed monitoring by satellites as an instrument for confidence building. Participants recognized the problems associated with the proposals for the establishment of an international satellite monitoring agency but felt that this matter should be kept under review and that consideration might be given to the possiblity of establishing regional monitoring agencies.

5. A special point was made to the effect that new agreements should be formulated so as to ensure the prohibition of antisatellite activities (ASAT's).

6. The participants also discussed certain issues connected with the interpretation of existing treaties and the divergences of interpretation. In this connection atten-

tion was drawn to the desirability of considering the terminology used in relevant instruments and, as far as possible, providing for a coherent use of definitions and terms.

7. In discussing applicable agreements, participants identified areas where a strengthening of existing rules would be required. Among these areas figured the desirability of strengthening and updating rules concerning information to be provided in connection with registration of space objects, the need for better communications in relation to settlement of disputes. Attention was also drawn to the need for including appropriate procedures for adjustment or rules in keeping with technological developments, scientific research and international cooperation in this field.

LIST OF PARTICIPANTS [1]

1. Professor Priyatna Abudrrasyid, Air & Space Law Research Center, 15, Jalan Banyumas, Jakarta, Indonesia.
2. Ambassador Abdel Abdel-Ghani, Former Deputy Secretary-General of UNISPACE Conference and Former Director of Outer Space Affairs Division, Sh. Osoris, Tagher Bldg., P.O. Box 262, Cairo, Egypt.
3. Mr. Abderrazak Berrada, member, International Frequency Registration Board, International Telecommunications Union, Palais des Nations, 1211 Geneva 20, Switzerland.
4. Prof. Dr. Karl-Heinz Böckstiegel, Director, Institut fur Luft- und Weltraumrecht der Universität Köln, Albertus-Magnus-Platz, 5 Köln 41, F.R. Germany.
5. Ambassador Robert Buchheim, Former Head of U.S. Delegation to U.S.-U.S.S.R. Negotiations on Anti-Satellite Systems and Activities, 312 East State Avenue, Phoenix, Arizona 85020, U.S.A.
6. Dr. Alexandre Carnelutti, Legal Adviser, French Embassy, 58 Knightsbridge, London SW1X 7JT, United Kingdom.
7. Dr. Carl Q. Christol, Professor of International Law and Political Science, University of Southern California, 1041 Anoka Place, Pacific Palissades, Ca 90272 U.S.A.
8. Prof. Dr. Aldo Armando Cocca, Ambassador-at-large, Juan Francisco Segui 4444, Buenos Aires 25, Argentina.
9. Mr. Sune Danielson, Permanent Mission of Sweden to the United Nations, 825 Third Avenue, 39th Floor, New York, N.Y. 10022, U.S.A.
10. Prof. Dr. I.H.Ph. Diederiks-Verschoor, President, International Institute of Space Law, Institute of Public International Law, University of Utrecht, Janskerkhof 3, 3512 BK Utrecht, The Netherlands.
11. Prof. Guya Gal, Legal Adviser, Lecturer in Air and Space Law, University of Budapest, Varga J.U.P./8 11.10, 1161 Budapest XVI, Hungary.
12. Mrs. Eilene Galloway, Honorary Director, International Astronautical Federation's, International Institute of Space Law, 4612, 29th Place N.W., Washington, D.C. 20008, U.S.A.
13. Prof. D. Goedhuis, Chairman, ILA Committee on Outer Space, Flat 37, Cadogan Square, London SW1, United Kingdom.
14. Prof. Stephen Gorove, School of Law, The University of Mississippi Law Center, Editor, Journal of Space Law, University, Mississippi 38677 U.S.A.
15. Mr. He Qizhi, Counsellor, Legal Advisor, Department of Treaty and Law, Ministry of Foreign Affairs, Beijing, People's Republic of China.
16. Ambassador Peter Jankowitch, Chairman, UN Outer Space Committee, Franziskanerplatz 5, Z-1010, Vienna, Austria.
17. Dr. Bhupendra Jasani, Stockholm International Peace Research Institute, Bergshamra, S-171 73 Solna, Sweden.
18. Mr. N. Jasentuliyana, Deputy Director, Outer Space Affairs Division, United Nations, New York, N.Y. 10017 U.S.A.
19. Dr. Vladimir Kopal, Director, Outer Space Affairs Division, United Nations, New York, N.Y. 10017 U.S.A.
20. Judge Manfred Lachs, International Court of Justice, Peace Palace, 2517 KJ The Hague, The Netherlands.
21. Dr. Nicholas Matte, Director, Institute of Air and Space Law, McGill University, 3690 Peel Street, Montreal, P.Q., Canada H3A 1W9.
22. Mr. B. G. Mayorski, Legal and Treaty Division, Ministry of Foreign Affairs, Smolenskaya-Sennaya Square 32/34, Moscow 121200 U.S.S.R.

[1] Participants were present in their personal capacity only.

23. Dr. Ogunsola Ogunbanwo, Co-ordinator, United Nations Disarmament Fellowship Programme, Department for Disarmament Affairs, Rm D612, Palais des Nations, Geneva, Switzerland.
24. Mr. G. S. Raju, Deputy Director, Legal & Treaties Division, Ministry of External Affairs, Patiala House, New Delhi-11 00 01 India.
25. Mr. Richard Saint-Martin, Counsellor, Permanent Mission of Canada to the United Nations, 250, 866 United Nations Plaza, New York, N.Y. 10017 U.S.A.
26. Dr. Paul Stares, Lecturer, University of Lancaster, U.K., Presently at Brookings Institute, 1775 Mass. Avenue N.W., Washington, D.C. 20036 U.S.A.
27. Mr. Ronald Stowe, Vice-President, Satellite Business System, 8283 Greensboro Drive, McLean, Va 22101 U.S.A.
28. Professor Hubert Thierry, Deputy Director, United Nations Institute for Disarmament Research, Palais des Nations, Geneva, Switzerland.
29. Mr. Edward W. Ploman, Vice-Rector, Global Learning Division, the United Nations University, 2-15-1 Shibuya, Shibuya-ku, Tokyo, Japan.

STATEMENT OF THE CENTER FOR DEFENSE INFORMATION, WASHINGTON, D.C.

STAR WARS: MYTH AND REALITY

On the face of it, everyone should welcome the hope held out by President Reagan's Star Wars plan, hope for a world in which nuclear weapons can be rendered "impotent and obsolete."

It is imperative, however, that we look beyond the glossy rhetoric and generalities with which Administration spokespeople have been trying to sell this scheme and search out the facts. We must strive to determine what kind of world a Star Wars defense would really bequeath to future generations. Such a searching examination exposes the President's vision as, at best, an appealing illusion. At worst, it is a cynical hoax on the American people. Far from making us more secure, pursuit of a Star Wars defense—estimated to cost between $300 and $1,000 billion—will only spark a new round in an already ruinously expensive and perilously dangerous arms race.

Support for the President's ill-considered proposal is founded on at least five pernicious myths.

First is the myth of MAD. A sponsor of last year's People Protection Act has claimed that, "What the President has proposed is no less than a moral recovery in American strategic policy which would take us from the horror of MAD [Mutual Assured Destruction] to the promise of mutual assured survival." This fallacy must be laid to rest, once and for all.

There is not, nor ever has been, an official U.S. MAD policy. Assured destruction is not a doctrine which can be discarded at will, any more than it can be replaced with "mutual assured survival." MAD is a tragic technological fact of life, an inescapable consequence of the United States/Soviet nuclear competition. And it is a fact of life Star Wars can do nothing to change. The Defensive Technology Study Team (Fletcher Report) acknowledged this in its statement that the proposed 5-year, $25 billion Star Wars R&D effort "drives [the Soviets] to try and develop possible countermeasures, increase emphasis on their air-breathing forces and conduct research and development on new families of weapons delivery systems." Far from disposing of the nuclear threat, Star Wars would only spur the development of new means of nuclear devastation.

The cost of building up our air defenses against new Soviet cruise missiles and bombers, which are immune to space weapons, must thus be charged to the Star Wars account. It would cost more than $100 billion simply to reconstruct air defenses equivalent to those we had in the early 1960's against a relatively small Soviet bomber force. It is more difficult to estimate what it would cost to attempt to counter such other feasible offensive measures as depressed trajectory submarine-launched missiles.

Second is the myth of the last move. It is illogical to assume that either superpower will abandon the capability of inflicting devastating damage on each other. It is naive to assume the means to continue to be able to do so won't be found. And it is insane to assume that a U.S. Star Wars effort will force the Soviets to concede U.S. superiority at the arms reduction table. Rather, as the Future Security Strategy Study (Hoffman Report) acknowledges, "they would be more likely to respond with a continuing buildup of their long-range offensive forces."

A central component of the Strategic Defense Inititiative is research into the means to counter a Soviet Star Wars system. The Soviets will work just as hard to

counter ours. Military history, available evidence and simple logic strongly suggest offensive countermeasures will remain cheaper than defensive measures.

Third is the myth of technological superiority. Too often in the course of the arms race we have assumed, because we are more advanced in a particular technology, that our lead gives us some concrete advantage. Always, our technological edge proves fleeting and we are soon confronted by the same weapons we train on the Soviet Union. MIRVs are perhaps the most notorious example of this recurring pattern, the long-range cruise missiles that will soon confront us are another.

The 1972 ABM Treaty presently prohibits both sides from mounting elaborate missile defenses. But we can't abrogate that treaty without the Soviets doing likewise. How much will it cost us to counter those Soviet defenses? How threatening will they appear to U.S. decisionmakers in the 21st century? Will future members of this Congress feel that we must build up our offensive forces to overcome Soviet space defenses? The future cost of penetrating or overwhelming a Soviet defense should also be charged to the Star Wars account.

Fourth is the myth that arms control agreements can be manipulated to our lasting advantage. We can reasonably assume that this Administration is unwilling to resume anti-satellite (ASAT) negotiations with the Soviets, as stated in its March 31 report, because it plans to use ASAT research (such as the Talon Gold experiment scheduled for later this decade) as a cloak for Star Wars field testing, currently banned by the ABM Treaty. The Administration indicates it would be willing to consider an ASAT treaty at some later date, presumably after a Star Wars architecture has been erected which unrestrained Soviet ASATs might threaten.

It is difficult to believe we could hope to get away with this sort of sleight of hand. The SALT/START process is already in serious trouble. Tampering with the ABM Treaty will do nothing to shore it up. Quite the contrary, uninhibited defenses will spark equally uninhibited offenses. Even Star Wars advocates acknowledge that the defensive mission will be possible only if coupled with agreements to limit offensive missiles. It is sheer folly, however, to believe that we can discard ABM restrictions and still expect agreement on U.S. START proposals; no superpower is going to bargain away its offensive, retaliatory capability in the face of an adversary's efforts to build a defensive system.

We must not rush off into an endeavor that will sabotage the one agreement that has actually limited arms, the ABM Treaty, without carefully considering the long-term consequences. The time for such consideration is now, before it is too late. Likewise, the prospect for an ASAT Treaty is now or never. Once more advanced ASAT technologies have been perfected there will be no squeezing the space-war genie back in the bottle. These treaties are like mutually-supportive building blocks; the policies of this Administration threaten to demolish the arms control edifice that has been carefully built up over the past two decades. It is imperative that we immediately resume space weapons negotiations neglected since 1979.

Fifth, last, and most disturbing is the myth that Star Wars is entirely defensive. It can't be emphasized strongly enough that space-based defense is part and parcel of a nuclear warfighting strategy. Far from making nuclear weapons "impotent and obsolete," ABMs in space will render them all the more usable. The difficulty of devising a Star Wars systems absolutely effective against a full first strike is widely acknowledged, even by the scheme's advocates. But this system might be effective enough against the ragged retaliation that would follow such a first strike. And Star Wars weapons would be more effective against the other side's defensive satellites if used in conjunction with that first strike.

It is unlikely that either side would have the confidence—or the desire—to launch a surprise attack backed up by space defenses in normal peacetime conditions. But in a superpower military emergency, such as the 1962 Cuban Missile Crisis, Star Wars would be one more incentive, in addition to the growing arsenal of highly accurate counterforce missiles, to strike first. The last thing we need in this unsettled world is yet more destabilizing weaponry.

For all these reasons, CDI strongly urges the members of this Committee, as you consider the space weapons proposals before you, to discard the myths and carefully scrutinize the realities. As a nation we have difficult decisions to make today that will govern the course of the arms race for decades to come. There have been too many missed opportunities in years past. This time, let us choose wisely and not make space the new battleground while there is still time to bar all weapons in space.

[Whereupon, at 4:10 p.m., the committee adjourned, subject to call of the Chair.]

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