Report of

Defense Science Board

1991 Summer Study

On

BALLISTIC MISSILE DEFENSE (U)

FEBRUARY 1992

Office of the Director of Defense Research & Engineering
Washington, D.C. 20301-3140

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OFFICE OF THE SECRETARY OF DEFENSE
WASHINGTON, D.C. 20301-3140

DEFENSE SCIENCE BOARD

MEMORANDUM FOR SECRETARY OF DEFENSE
UNDER SECRETARY OF DEFENSE FOR ACQUITION

SUBJECT: Report of the Defense Science Board (DSB) 1991 Summer Study on Ballistic Missile Defense - ACTION MEMORANDUM

I am pleased to forward the final report of the DSB Summer Study on Ballistic Missile Defense (BMD), which was chaired by Mr. Daniel Fink, Mr. Fred Hoffman and Mr. William Delaney. The objective of this study was to consider the requirements for tactical and theater ballistic missile defenses; their interaction and interfaces with CONUS BMD; recommendations for development and deployment options; the necessary technological underpinning; ABM treaty implications and other related policy issues.

The task force focused on theater missile defense and emphasized active defense against tactical ballistic missiles. The task force concluded that both near-term and mid-term approaches to active theater BMD are well positioned. An aggressive schedule to upgrade the Patriot and the upgrade of the Navy's Aegis were the more significant near-term recommendations.

The SDIO efforts involving the Ground Based Radar and the Theater High Altitude Area Defense missile were highlighted as sound approaches to counter expected theater missile threats. The lethality of our conventional defensive warheads against certain classes of enemy chemical and biological warheads was a task force concern.

I recommend that you review the Executive Summary and the management issues and recommendations (pages 28-30) which highlight the findings, recommendations and implementation actions.

John S. Foster, Jr.
CHAIRMAN

ATTACHMENT (S)

OFFICE OF THE SECRETARY OF DEFENSE
WASHINGTON, D.C. 20301-3140

DEFENSE SCIENCE BOARD

Dr. John S. Foster, Jr.
Chairman, Defense Science Board
The Pentagon
Washington, DC 20301-3140

Dear Johnny:

Enclosed is the Final Report of the Defense Science Board/Defense Policy Board Task Force on Ballistic Missile Defense (BMD), which was part of the 1991 Defense Science Board Summer Study.

We focused our attention on theater missile defense and emphasized active defense against tactical ballistic missiles (TBMs). We believe the study and its results are particularly timely in light of the Desert Storm experience coupled with the continuing proliferation of TBMs and associated technologies among Third World nations. The threat to U.S. forces overseas and to our allies and friends exists and is likely to increase.

Overall, the Task Force concluded that the United States is favorably positioned with both near-term and mid-term approaches to active theater BMD. We recommend an aggressive schedule to upgrade the Patriot as our major near-term response. The result will be a system much improved over that which we were able to field in Desert Storm. The upgrade of the Navy's Aegis is also an important part of our recommendations for the near-term.

We also recommend proceeding with the SDIO developments involving the Ground-Based Radar and the Theater High Altitude Area Defense missile as a sound approach to counter the more difficult theater missile threats our forces can be expected to meet within the next decade. A variety of space systems can provide critical alerting and support to all of these active defense systems, and we highlight the promising R&D in that area.

The Task Force is concerned with one area of technology that is critical to the success of all future theater missile active defense systems: the lethality of our conventional defensive warheads against certain classes of enemy chemical and biological warheads. We need to sustain a strong national effort in technology, development, and experimentation in this field. We recommend the continuation and enhancement of SDIO and DNA efforts in this area.

We are all very pleased to have participated in this important DSB/DPB endeavor.

Daniel J. Fink
Co-chairman

Fred S. Hoffman
Co-chairman

William P. Delaney
Co-chairman

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EXECUTIVE SUMMARY: BALLISTIC MISSILE DEFENSE TASK FORCE (U)

(U) The Task Force on Ballistic Missile Defense focused its attention on theater missile defense (TMD). This was a combined Task Force of the Defense Science Board and the Defense Policy Board so that both technical and policy issues of ballistic missile defense (BMD) were addressed. Our focus was on active defense, that is the intercept and negation of the enemy's ballistic missile (BM) warheads after launch.

(U) Theater ballistic missile (TBM) threats are proliferating, but the situation is different than it has been during the preceding 40 years of Soviet BM development. First, Third World Nations can obtain BM systems by simple transfer. Thus, these systems can arrive suddenly and without warning. Second, these systems will not be tested nearly as vigorously by the developer as Soviet systems were tested; they may be tested rarely by the users. Thus, we may have little insight into or information about the threat specifics. Our TMD, therefore, must be designed with substantial flexibility to accommodate these uncertainties.

(U) Most of today's threats are limited-capability Scuds and Scud variants. Much more capable systems are likely to be part of the threat in the future, and these need to be factored into our planning for TMD systems. One example of the more capable threat is the Chinese CSS-2 missile, which has a range of 3000 km—about five times that of the Iraqi Scud variant.

(S) With regard to implications of the ABM (Anti-Ballistic Missile) Treaty for TMD, the Task Force recommends that [redacted]

(S) The Task Force considered upgrading the Patriot system and strongly recommends these improvements. [redacted] Upgrading existing systems permits us to capitalize on this inventory and infrastructure. The upgrade is relatively straightforward and can dramatically enhance Patriot's capability against TBMs.

(U) A similar set of arguments leads the Task Force to recommend that the Navy's Aegis system also be upgraded to have significant capability against TBMs. Importantly, the Navy may have the only on-the-scene TMD capability at the onset of many conflicts and will be sorely needed for defense of both sea and air ports-of-entry and for protection of amphibious landing forces. The Navy's presence and large ship platforms coupled with modern interceptor and sensor technologies convince the Task

Force that the Navy can make a substantial TMD mission contribution beyond traditional Navy missions.

(U) An important question is whether new and more advanced TMD systems are needed beyond the upgrade of Patriot and Aegis. The Task Force concludes that more advanced capabilities are necessary and should be pursued aggressively. The primary reason for this conclusion is that more advanced threats (e.g., longer range threat missiles, more threatening front ends, and technologies that can make warheads more difficult for our TMD systems to find and kill) require more advanced defenses. The Strategic Defense Initiative Organization (SDIO) is developing a ground-based system comprised of a ground-based radar (GBR) derivative and the Theater High Altitude Area Defense (THAAD) missile, which the Task Force concludes is well matched to the advanced system role. The GBR also can be a valuable cuing source to a system such as Patriot.

(C) [redacted]

(U) Space systems, such as the DSP (Defense Support Program) system and its upgrades*, and more capable systems, such as the Brilliant Eyes (BE) satellite constellation, can provide significant contributions to all TMD systems. A cue from space providing the location of a BM launch or a more exact threat-missile flight path can allow a ground-based TMD system to defend areas two to four times larger than could be defended without the assistance from space. Thus, the Task Force recommends a vigorous program of upgrades and new developments in the area of space systems.

(U) The Task Force comments on a number of management issues related to US TMD efforts. TMD is a new mission; it is a National mission; and it is a joint-Services mission, which requires substantial effort and cooperation between the Services and the SDIO. This challenge arrives at a time when budgets, manpower, and forces are shrinking substantially. The Task Force makes several recommendations to help sustain a concerted attack in this important area.

*The Task Force considered FEWS to be the follow-on to the DSP system. Throughout this document and appendices, therefore, "DSP" is used to mean not only the existing system but FEWS as well.

I. INTRODUCTION (U)

(U) At the request of the Under Secretary for Defense (Acquisition), the Joint Defense Science Board/Defense Policy Board Task Force on Ballistic Missile Defense was formed on May 15, 1991 "to consider the requirements for tactical and theater ballistic missile defenses; their interaction and interfaces with CONUS BMD; recommendations for development and deployment options; the necessary technological underpinning; ABM Treaty implications and other related policy issues." The Terms of Reference (TOR) further elaborated this task by setting forth a series of topics for the Task Force to address (see appendix A).

(U) In conducting its work, the Task Force recognized that TMD, broadly defined, comprises four elements: active defense against incoming BM warheads, passive defense of military and civilian targets, counterforce wherein theater missile launchers are located and destroyed before they can launch their missiles, and the command and control structure that relates these elements. Further, the theater missile threat can include cruise missiles (CMs) and air-to-surface missiles. The TOR, however, made active defense against surface-to-surface BMs the central focus of the Task Force. Considerations of time, resources, and interrelatedness dictated how far the Task Force pursued the associated topics listed in the TOR or included within the full scope of TMD.

(U) The Task Force brought together a talented and experienced group of individuals who were assisted by a knowledgeable cadre of Government Representatives. Task Force members are shown in table 1.

TABLE 1.—Members of the Task Force on Ballistic Missile Defense (U)

Co-chairmen: Mr. Daniel Fink,† Mr. Fred Hoffman		
Dr. J. Beyster	Mr. L.D. Montague	Mr. E. Donalson#
Dr. C. Bostrom*	Prof. D. Nosenchuck	Dr. E. Gerry#
Dr. J. Braddock*	Gen (Ret) J. Piotrowsky	Dr. K. Goering#
Mr. R. Cattoi*	Mr. S. Tennant*	Dr. S. Gold#
Mr. W. Delaney†	Gen (Ret) J.Vessey**	Dr. W. Howard#
Gen (Ret) R. Dougherty*	Amb. S. Weiss**	Mr. L. Minichiello#
Mr. R. Everett*	MG (Ret) J. Welch	Dr. P. Pappas#
Mr. M. Fossier	Amb. R.J. Woolsey	Dr. B. Pierce#
Dr. W. Graham**	Dr. S. Zeiberg	Col D. Ross
Hon. F. Ikle**	Dr. S. Cambone#	Mr. A. Viilu#

*Defense Science Board **Defense Policy Board #Government Representative

†Part way through the Summer Study, Mr. Fink was involved in an accident; Mr. Delaney ably assumed Mr. Fink's responsibilities.

UNCLASSIFIED

(U) Topics considered by the Task Force and discussed in this report are

(U) The Threat
(U) US National Security Objectives
(U) ABM Treaty Issues
(U) Patriot Upgrades
(U) Lethality of Defensive Warheads
(U) Countermeasures
(U) Advanced TMD Systems
(U) Navy Role in TMD
(U) Space Systems Contributions
(U) Management Issues
(U) Recommendations

(U) In addition, there are five appendices; the last four consider specific topics in more detail.

(U) Appendix A: Terms of Reference
(U) Appendix B: How Much Footprint Is Needed in a TMD System?
(U) Appendix C: Lethality of TMD Warheads
(U) Appendix D: Countermeasures—Penetration Aids
(U) Appendix E: Related Issues

II. THE THREAT (U)

A. CHANGES IN THE INTERNATIONAL ENVIRONMENT (U)

(U) The Task Force convened at a time when events were forcing fundamental reassessment of US strategy and priorities—a reassessment likely to continue well into the future. The demise of the Warsaw Pact and the economic (and possible political) collapse of the Soviet Union provide a context for a turn in Soviet policy from one of hostility to one of cooperation. The unsuccessful coup that greatly accelerated the process of change in the Soviet Union occurred during the course of the Task Force's 1991 Summer Study. These events point to the disappearance of the major threat that has driven US strategy. But Soviet general purpose forces remain the preponderant military power in Eurasia; no appreciable slackening in Soviet strategic programs is yet evident; and the outlook for continued peaceful, democratic change and economic recovery is far from reassuring.

(U) With the attenuation of the traditional Soviet threat, more diverse threats have been intensifying. Signs of a possible collapse of central authority in the Soviet

Union have made the West apprehensive about the stability of control over Soviet strategic forces as some of the increasingly autonomous republics have asserted control over military forces within their borders. Well before the recent Soviet changes, the spread of BMs and of the technologies for manufacturing and upgrading them had become an increasing concern, heightened by the associated spread of technologies for nuclear, biological, and chemical (NBC) weapons of mass destruction. Iraq's attempt to use the Scud missile for strategic as well as tactical benefits during Desert Storm greatly intensified this concern as did the discovery after the conflict that the international community had vastly underestimated the extent and achievements of Iraq's advanced weapons programs and that it may now be underestimating those of Iran. Most recently, President Gorbachev's response to President Bush's October initiative speeding the deactivation of strategic missiles and withdrawing a large part of our theater nuclear missiles from forward deployment has included a new expression of willingness to consider limited deployment of BMDs; a restatement of Soviet opposition to deployment in space was notably absent.

B. THE THEATER BALLISTIC MISSILE THREAT (U)

(U) Assessing the TBM threat as a basis for our TMD program calls for a different process than the one the United States has been dealing with the Soviet threat. For over 40 years we have been tracking Soviet military forces, estimating their order of battle, and observing closely the development, testing, and strategic use of their technologies. In our requirements process, we assumed we could rely on continuity in the development of Soviet posture to project the threat to be countered. The recent changes in the international environment indicate that this approach is irrelevant to the planning processes we now need, especially in relation to the TBM threat.

(U) A body of data and experience such as that accumulated on the Soviet military is lacking for the assessment of the threat our TMD systems will have to counter. Third World countries that acquire weapons or technology by transfer from more developed countries are the most likely source of TBM threats. While the supplier countries *may* test during development, the United States does not maintain the level of surveillance over all of them that it does over the Soviet Union and may not, therefore, acquire technical data even if they do test. Even more troublesome, the transferred weapons or technologies will not, in general, be the tested versions, and the recipient countries rarely test before using. Consequently, we can count on little or no warning time between seeing a new or modified threat and facing it in the field. Under such circumstances, we cannot base our requirements and acquisition processes on estimates of a time-phased threat with well-defined characteristics. Our systems design and acquisition process will require built-in flexibility and fast response to meet threats as they appear.

(C) Today, there are about 15 BM families, but the threat consists primarily of approximately 9,400 Scud and Scud variants with about 1,100 launchers in some 19 countries. In addition, [redacted] and about [redacted] The Scuds and their variants have ranges from 300 to 600 km and carry, primarily, high-explosive (HE) warheads. These missiles are inaccurate, with CEPs (circular error probable) of over 1,100 m. The characteristics of the Scud family restrict it to use primarily against urban targets—as a weapon to intimidate local populations or their governments. But with chemical or biological warheads, Scuds (and their variants) might have some effectiveness against military targets.

(S) Improvements in CEP and increasing warhead lethality (chemical and biological agents and HE—all packaged in submunitions—and possibly nuclear warheads) are likely to give Third World BMs the ability to disrupt military operations by directly attacking critical military targets, [redacted] The number of countries possessing such weapons can be expected to increase to about 20, and as many as five may be producing and modifying the missiles. Longer ranges will allow aggressors to threaten potential US coalition partners remote from the scene of aggression and to intervene in conflicts remote from their territory.

III. US NATIONAL SECURITY OBJECTIVES IN THEATER MISSILE DEFENSE (U)

A. THE RECENT HISTORY OF THEATER MISSILE DEFENSE AS AN ELEMENT OF BALLISTIC MISSILE DEFENSE POLICY (U)

(U) Protection against BMs attacking theaters of operations has been an objective of the Strategic Defense Initiative (SDI) since its inception. In his 1983 speech announcing the SDI, President Reagan referred to its mission as that of protecting "our own soil or that of our allies." In 1983, the Future Security Strategy Study (conducted by White House directive in parallel with the Defense Technology Study) concluded that defense against theater ballistic missiles "is an intermediate option [on the path to President Reagan's goals for the SDI] . . . that might be available relatively early . . .. Such an option addresses the pressing military need to protect allied forces as well as our own theaters of operations from either nonnuclear or nuclear attack." The role of SDIO technologies in theater defense was also recognized in the review of the SDI directed by Ambassador Cooper in 1990 and in the 1990 Defense Science Board Summer Study on Research and Development Strategy for the 1990s.

(U) It should be noted here that from its inception, the SDIO has sought to foster allied cooperation in the development of technology, emphasizing allied interest in the development of advanced TMDs.

(U) In his State of the Union Address in January 1991, President Bush announced that he had directed "that the SDI program be refocused on providing protection from limited ballistic missile strikes, whatever their source . . . to deal with any future threat to the United States, our forces overseas, and our friends and allies." In response, the Department of Defense (DoD) formulated the defense concept of Global Protection Against Limited Strikes (GPALS). On February 7, 1991, Secretary Cheney testified before the House Armed Services Committee that GPALS "includes theater missile defense to protect US and allied troops deployed abroad" and that the "SDIO has been charged with developing advanced defense technologies to deploy much improved, transportable theater missile defenses within the next 5 years." Experience in Desert Storm involving Scud missiles and Patriot defenses against them has also intensified interest in the role of BMD in regional contingencies to protect US forces as well as allied forces and territory.

(U) Even before Desert Storm, the Congress demonstrated increasing interest in systems for protection against limited strikes and, especially, in TMD. In its FY 91 budget action, the Congress *increased* the TMD authorization from the $144 M requested by the SDIO to $180 M; it also created the Theater Missile Defense Initiative and provided an additional $218 M to fund it. It is significant that this support for TMD was provided at the same time the overall SDIO authorization was reduced from $5.15 B to $4.15 B.

(U) In response to a Conference Committee request that DoD "establish a centrally managed tactical ballistic missile defense research and development program under the auspices of the Office of the Secretary of Defense," the Secretary designated the SDIO as that management office. The House Armed Services Committee *Summary of Major Actions by the House-Senate Conference on the FY 92 Defense Authorization Act* (November 1, 1991) makes is clear that congressional support for TMD will continue through FY 92. The Conference allocated $842 M to TMD, only slightly less than the $855 M requested by the Administration; the Conference explicitly prohibited the SDIO from reprogramming the funds for other purposes. The Conference directed "the Secretary of Defense to aggressively pursue the development of a range of advanced theater missile defense options, with the objective of deploying such improved systems by the mid-1990s" and adopted a provision "urging the President to discuss with the Soviets the feasibility and mutual interest of amending the ABM Treaty."

(U) In sum, new factors are making it more urgent to deploy limited but capable BMDs while previous centers of opposition to BMD programs are showing increased willingness to support or consider deployment of, at the least, systems of limited capability and particularly systems for TMD. The Task Force identified needs and opportunities for action in the short term while protecting and advancing options to realize longer term goals.

B. DISTINCTIVE ASPECTS OF THEATER MISSILE DEFENSE OBJECTIVES (U)

(U) To deter attacks on allies and friends of the United States in regional conflicts poses different problems than did deterring a Soviet attack on Western Europe. Although the credibility of US threats to use its strategic nuclear forces to respond to a conventional attack by the Soviet Union has long been questioned (such a response is incompatible with the state of mutual deterrence supposed to have existed between the United States and the Soviet Union), the unquestioned and vital US interests in the independence of Western Europe were generally believed to be sufficient to deter Soviet attack. Few, though, believe that an analogous state of mutual deterrence would keep leaders such as Saddam Hussein from exercising local military superiority against their neighbors.

(U) Third World adversaries may be far less powerful but more difficult to deter than the Soviet Union. The rationality of specific leaders will often be less reliable and their hold on power less secure than was commonly believed to be true of Soviet leaders. To deter Third World leaders, the US posture—that we will oppose aggression in conflicts that those leaders may see as involving their vital interests but which they believe are (or could be made to seem to be) peripheral to our interests and to the interests of those who might cooperate with us—must be credible. Moreover, in future conflicts, it would be imprudent to count on all the advantages that contributed to the outstanding success of Desert Storm. The sensitivity of public opinion in the West to friendly casualties and to widespread civilian casualties among our adversaries rules out a strategy of massive retaliation as an effective deterrent to regional aggression. Experience shows that threats of extreme response lack credibility in the eyes of regional aggressors, creating a situation in which the likelihood of conflict is higher than it has been in Central Europe.

(U) Stability is such cases requires a clear US capability to intervene in a way that is politically acceptable as well as militarily effective. In particular, we should not assume that we will have as much time to deploy our forces before combat begins. The United States might face the task of deploying forces while under attack. BMs carrying NBC warheads would pose a special threat to logistics operations during large-scale deployment with its inevitable concentration of assets in a relatively small number of critical facilities. Such a possibility means that BMD could be needed at the outset of a deployment and has important implications for the character of the TMD systems we develop.

(U) The spread of weapons of mass destruction is giving new prominence to the TMD task of protecting allied populations and infrastructures in addition to US and allied forces. This task is often characterized as "non-military," but such a characterization misses the point. The ability to intimidate the object of aggression or a neighbor that might cooperate with the United States in resisting aggression may have profound strategic impact. In the future, it may be necessary for the United States to offer a degree of protection against terror attacks as a condition for obtaining strategic access to a theater of combat. And, as the range of Third World BMs increases, they will allow aggressors to threaten potential US coalition partners remote from the scene of aggression. For example, with such a longer range capability, Saddam Hussein might have made it much harder to obtain the cooperation of some European countries in the recent crisis. Longer range will also permit countries to intervene in conflicts remote from their own territory.

(U) The unpredictability and variety of the threats makes it especially essential to build flexibility into our TMD design and acquisition processes. It also should warn against driving the processes by adopting extreme performance requirements that may delay or prevent the United States from acquiring capabilities useful against many plausible threats.

IV. ABM TREATY ISSUES (U)

A. THE ABM TREATY AND THEATER MISSILE DEFENSE (U)

(U) For the 8 years since its inception, the large and highly visible SDI program has had as its ultimate aim the deployment of an effective National Missile Defense (NMD). It has done so within the ambiguous limits set by the ABM Treaty, a treaty designed to prevent such a deployment. The technical community was not directed to lay out an optimal development plan but, instead, to proceed within Treaty constraints until the United States made a decision to deploy. As a result, there is no baseline reference program permitting the Task Force to assess the Treaty's impact on the SDI program. Of special interest to the Task Force, however, is the fact that the Treaty's impact extends beyond our NMD efforts to affect TMD programs.

(U) Nowhere does the ABM Treaty explicitly refer to TMD. It addresses only so-called "ABM systems" and defines them as defenses against "strategic missiles." The Treaty is an issue because the distinction between the performance and technical capabilities of ABM and TMD is unclear today and likely to become progressively less clear as TBM threats grow in range and capability and as technology increases the effectiveness of defenses against them.

(U) Further, the Treaty issue has acquired urgency with the emergence of a consensus in favor of deploying a limited NMD and an even broader consensus for initiating deployment of a TMD system by mid-decade. If the TMD mandate is taken to include deployment of a system such as the THAAD/GBR, there are important implications both for program management (discussed in section XI) and for the US approach to the ABM Treaty.

(U) As noted above, among the actions of the House-Senate Conference on the FY 92 Defense Authorization Act is a request that the President initiate discussions with the Soviet Union leading to revision of the ABM Treaty. Earlier, the Senate, in approving the Missile Defense Act of 1991, listed among the proposed objectives not only making the revisions necessary to permit an effective NMD but also clarifying the distinction between ABM and TMD systems. The Soviet Union recently proposed that we agree on missile performance limits beyond which testing would be prohibited under Treaty. In 1972 Senate testimony during the ABM Treaty ratification process, the Administration asserted its unilateral understanding concerning the altitude and speed of interceptor missiles permitted under the Treaty's limits on testing (the "Foster box"). In practice, however, we are approaching another ABM Treaty 5-year review period, which will also add to pressures to consider revisions.

(U) Policy toward revising the Treaty must, therefore, consider both how the Treaty or revisions to it impact the TMD program and how resolution of the TMD Treaty issues might impact a global defense such as GPALS. The Task Force has identified four policy alternatives.

1) Exercise our latitude under the Treaty and do not pursue early revisions.

2) Take up the Soviet initiative to agree on missile performance limits beyond which testing would be prohibited.

3) Revise the Treaty for short-term objectives such as those in the Senate-passed Missile Defense Act.

4) Reopen the Treaty only for revisions sufficient to permit effective BMD development programs in pursuit of long-term goals such as deployment of GPALS and subsequent system growth when desirable.

B. FINDINGS ON THE ABM TREATY (U)

(U) Deciding which of these alternatives to pursue depends upon the judgments made about, first, the likelihood that we could reopen the Treaty within a reasonable time after making limited revisions and, second, how far we can proceed under the latitude permitted in the Treaty without revisions.

(C) Regarding the likelihood of reopening Treaty discussions after making limited revisions, the ABM Treaty not only is of indefinite duration but also has a high policy profile. [redacted]

(U) Regarding the latitude permitted under the existing Treaty, to establish a working definition the latitude for testing and deploying advanced TMD systems, such as the THAAD/GBR, two approaches have been suggested: 1) Take the Soviet SA-12 system as defining the permissible limits of capability for testing or deploying a TMD and 2) Take as the lower bound of an ABM system the capability to intercept (or having been tested against) a "strategic missile," defined as the least stressing missile in the Soviet inventory as of the relevant date. Neither offers full freedom for the TMD options under consideration, and congressional reaction to either is uncertain.

(S) Regarding the first approach, [redacted] Regarding the second approach, [redacted] will probably encounter Treaty problems unless revisions are made to remove all limits on sensors.

(U) Under the second and third policy alternatives, the United States would seek to reach agreement with the Soviet Union on, among other matters, a distinction between ABM and TMD that gives us the latitude we need to pursue our advanced TMD programs. Despite the attractiveness for the short term, such revisions incorporated into a Treaty of unlimited duration could create serious problems in the long term. If the revisions are too modest in the latitude they allow for TMD systems, we will be unable to keep up with the threat or take advantage of advancing technology. If the revisions permit greater latitude for TMD, however, increasing TMD's overlap with ABM and permitting free deployment of the former while continuing to restrict the latter, we must take into account the geostrategic asymmetry between the United States and the Soviet Union (or its successor states). While our TMD would be intended for deployment overseas, the Soviet's would be operationally deployed to meet TBM threats within its home territory. In numbers plausible for the TMD mission and with continuing technological advances, a future Soviet system approximating or exceeding the capability of THAAD/GBR might well impinge on the strategic balance, especially if strategic forces are reduced substantially below the START levels.

(U)(U) [redacted]

V. PATRIOT UPGRADES (U)

A. INTRODUCTION (U)

(U) TMD includes a number of existing or proposed active defense components and systems such as Patriot, Aegis, THAAD, GBR, ERINT (Extended Range Interceptor), Arrow, DSP, BE, and Brilliant Pebbles (BP). These include ground-based, sea-based, and space-based components and systems. The Task Force placed particular emphasis on Patriot (and its upgrades), Aegis, THAAD/GBR, DSP, and BE.

B. PATRIOT TODAY (U)

(U) Patriot is our most advanced ground-based air-defense system. Deployment began in 1985 and today represents a US investment of approximately $12 B. Allowing for foreign sales and some production by allies, the worldwide Patriot inventory would be about 10,000 missiles by CY 2000. The modifications (PAC-1 and PAC-2) to allow intercept of short-range BMs are relatively recent and represent a cost of $140 M, which is little more than 1% of the US investment to date.

(~~C~~) While the Patriot PAC-2 did well in Desert Storm,* it has limitations. The size of the defended area and the altitude at which intercepts can be made are both

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*There is continuing debate on just how well Patriot performed in Desert Storm. The Army's investigations conclude that Patriot had a relatively high kill probability against the modified Scud, even though the Scud had unexpected characteristics that created some difficulties for Patriot. (See section VII: Countermeasures.) Those who argue that Patriot did poorly generally focus on the issue of the lethality of the Patriot warhead. (See Section VI: Lethality of Defensive Warheads.) The issue may never be firmly resolved due to a lack of *detailed* data on the actual intercept events.

The Task Force observes that there are an infinity of ways in which a complex system such as Patriot will not work well in its first actual combat, particularly against a threat with some "surprises." Our view is that the system performed quite well in a technical sense. Radars, missiles, computers, and command and control hardware all functioned reliably, and the operators were able to adapt quickly to the surprises in the threat. Although Patriot's performance was not perfect, the results could easily have been dramatically worse.

limited. The size of the Patriot elements is such that they cannot be carried on C-141 or C-130 aircraft without extensive disassembly; this, of course means that reassembly in the field, possibly while under attack, is also required. [redacted] These topics will be discussed below.

C. POTENTIAL PATRIOT UPGRADES (U)

(C) There are straightforward modifications to Patriot that can greatly increase its robustness against such threat variations. These modifications include [redacted] These changes also contribute to Patriot's ability to defend against low-observable *air* vehicles [redacted] Repackaging the existing radar and launchers onto smaller trucks allows C-130 and C-141 roll-on/roll-off capability. These improvements are called QRP (Quick Response Program) and PAC-3. The Task Force addressed them collectively as "Patriot upgrades."

(U) The total cost (R&D and production) of the Patriot upgrade program is about $1.8 B; this includes procuring 1,000 new missiles with the new seeker and retrofitting the radars. The Army's milestone schedule for the full PAC-3 change allow an Initial Operating Capability in 1997 with some QRP modifications fielded in 1993.

(U) An important question concerning these upgrades is how much more TMD capability they will yield. One standard measure of defense system capability is footprint—the contour that encompasses all points on the ground defended by a single battery against a particular threat missile. Footprint is not the full measure of capability. Intercept altitude, lethality, and countermeasure resistance—among other factors—also are important variables, but more capable systems, overall, tend to have larger footprints so we use it to illustrate relative capabilities of various systems. The size of the footprint varies with both target and defense system characteristics. Factors that increase the target detection range and the defensive-missile-to-target-missile velocity ratio will increase the footprint. Thus, the footprint is larger against shorter range TBMs (which have a lower velocity) and higher signature TBMs and for systems with better radar sensitivity and high defensive missile speeds.

(S) Figure 1 shows a series of estimated footprints for various levels of Patriot upgrades. They are drawn for an attacking ballistic missile with a [redacted] These footprint estimates are based on simple radar detection and tracking calculations and simplified Patriot missile kinematics. They do not take into account the more complex, but important, details such as miss distance, Patriot warhead lethality, or enemy countermeasures. Thus, they tend to represent an upper bound on Patriot performance.

[redacted]

FIGURE 1.—Patriot Footprints Against Threat Missile With 600-km Range and 0.1-m^2 RCS (U)

(S) The innermost footprint is for the Patriot PAC-2, the system used to counter Scud attacks during Desert Storm. It provides coverage for targets about [redacted] While such a footprint might be adequate for defense of small targets such as an airfield, it is too small for urban area defense, and it provides limited battlespace and intercept altitudes for most defensive missions. (How much footprint one needs is an important question addressed in appendix B.)

(S) The two phases of the upgrade program increase the footprint in steps as shown—to about [redacted] for the QRP first phase and to more than [redacted] forward for the full PAC-3 upgrade—primarily due to the increase in radar sensitivity, addition of an active seeker on the missile, and the ability to separate launcher sites from radar sites. Associated with these footprint increases are increases in maximum intercept altitude, from the [redacted] These altitude improvements come from changes in the missile guidance system. There are a number of benefits to higher altitude intercepts such as dispersing biological or chemical agents more widely and having debris fall outside of the intended target area.

(S) Cuing the radar is a powerful technique as illustrated in the two outermost footprints in figure 1. Cuing involves defining the threat corridor to allow the radar to limit its search volume. This increases the detection range because radar power can be concentrated. Information from two DSP satellites working cooperatively—stereo DSP (SDSP)—can be used as a relatively coarse cue, [redacted] Precise cuing of the Patriot radar to one or a very few beamwidths could be provided from sources such as the GBR or BE. This allows greater concentration of Patriot radar power and increases the footprint to about [redacted] This would utilize most of the kinematic capability of the Patriot missile.

(S) Footprints with [redacted] are sufficient for efficient defense of military targets and of the population centers of most countries in the world (see appendix B). However, such footprints cannot be sustained against threats more difficult to counter than the somewhat primitive Iraqi Scud. For example, the forward point of the footprint in figure 1 with SDSP cuing is [redacted] This is reduced to 53 km if the target radar signature is reduced from [redacted] such as might be expected in the future. For longer range TBMs [redacted] assuming a lethal intercept against such a fast target is, indeed, possible with a Patriot missile.

D. FINDINGS ON THE PATRIOT (U)

(U) The Task Force is convinced that upgrades to the Patriot missile make sense and recommends that the planned upgrades proceed with deliberate haste. The principal arguments for vigorously proceeding are summarized below.

(C) Figure 1 shows that there is a large payoff to the Patriot upgrades. Comparison of the innermost and outermost footprints demonstrates a [redacted] increase in defended area in the extreme case; a [redacted] increase in defended area is a conservative lower bound. This can be achieved for about 10% more investment in Patriot. Economies to be realized by using the existing production base and logistics infrastructure are important supporting arguments. The technical features of the upgrades appear to be straightforward and of low risk.

(C) Most situations requiring TMD also will require a defense against air vehicles. Patriot, as the principal ground-based air-defense system, will most probably be deployed in the theater anyway. The advantage of providing both air defense and TMD with the same system is an important consideration. The PAC-3 upgrades to radar power, radar sensitivity, and missile seeker performance contribute to an improved air-defense capability against threats such as CMs.

(C) The enhancement of Patriot TMD performance by external cuing is valuable for obtaining the maximum benefit from the Patriot investment. [redacted] This is an important benefit of the SDIO GBR effort. Precision cuing is also possible with advanced space surveillance systems such as BE satellites—a topic discussed later.

(C) The Task Force has a sense of urgency to move quickly with these relatively straightforward modifications. It believes the Army's schedule for the Patriot PAC-3 upgrades could and should be accelerated by 1 to 1½ years.

VI. LETHALITY OF DEFENSIVE WARHEADS (U)

(C) The Task Force's major technical concern involved the lethality of our conventional (as opposed to nuclear) defensive missile warheads against some of the offensive warheads expected to be deployed. Biological and chemical warheads do not need to be sophisticated to cause concern. [redacted] Lethality is a complex topic that is treated in appendix C. A synopsis is provided here.

(C) [redacted]

(U) Figure 2 depicts two types of warheads used to deliver biological and chemical agents. The bulk warhead holds the agent in one large container. This container can be ruptured readily by the near miss of a fragment warhead or the impact of a hit-to-kill (HTK) warhead. The agent itself would, in most cases, be dispersed by the wind to nonlethal densities provided the intercept occurred at a sufficiently high altitude.

(S) The situation is much less favorable for the submunition warhead; it may contain 50 to 100 individual canisters intended to be dispensed at low altitude. The individual canisters may be extremely rugged, resembling thick-walled steel pipe bombs. [redacted]

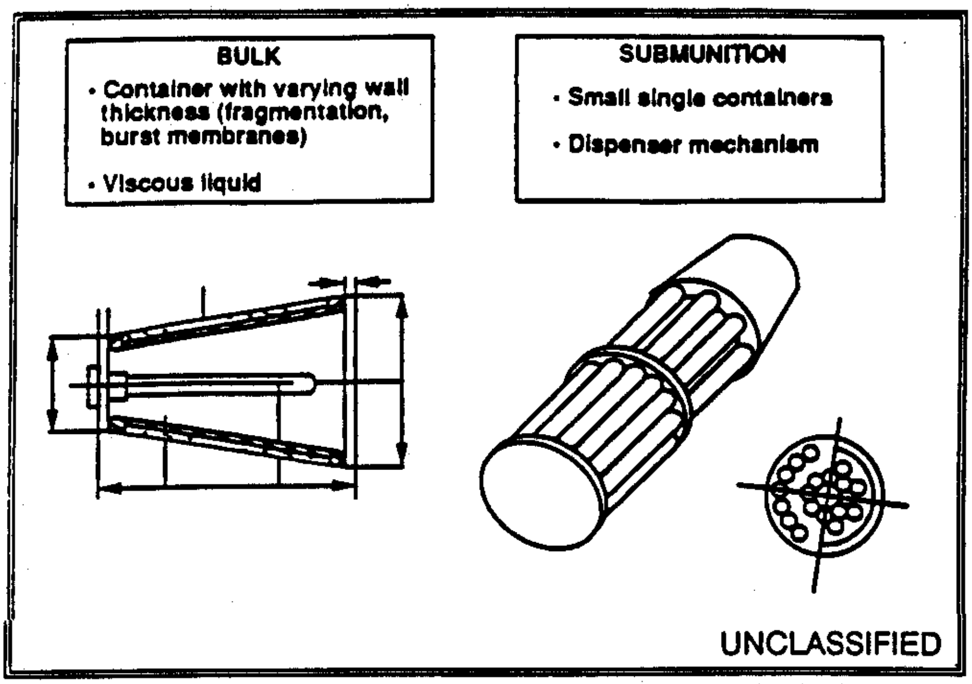

FIGURE 2.—Two Types of Warhead for Delivery of Biological and Chemical Agents (U)

(U) The Task Force believes there is opportunity for substantial improvement in defensive warhead effectiveness. This area has not been intensely explored although activity has increased recently. A substantial (SDIO/DNA) program should be supported. It should address the spectrum of threat engineering possibilities and explore capabilities of individual and combined lethality mechanisms. There should be substantial lethality upgrade activity for the Patriot and Aegis missiles.

(S) In view of the uncertainty in this critical area, the Task Force argues strongly that new interceptors (e.g., THAAD, ERINT, LEAP) be designed with a lethality hedge in weight and volume. The weight and volume would be used to build in lethality-enhancing devises [redacted] A preliminary analysis of the THAAD interceptor shows that an addition of [redacted] would not cause a substantial penalty in missile kinematic performance.

VII. COUNTERMEASURES (PENETRATION AIDS) (U)

A. INTRODUCTION (U)

(U) Penetration aids (PENAIDS) appear in the reentry object train automatically, even for the simplest missile system. The Scud is a good example because we have data from its use in Desert Storm, the Iran-Iraq War of the Cities, and Afghanistan. Two PENAIDS come "free" with the Scud system: fragmentation of the unseparated missile tank and spiral maneuvering that results from the aerodynamic forces acting on the asymmetric, partially fragmented tank. In addition, high-rate attacks were used in the conflicts cited—up to 25 missiles per hour in the War of the Cities and up to 10 per hour (with as many as 7 in the air simultaneously) in Desert Storm. Countermeasures are discussed in more detail in appendix D. The following summarizes the Task Force's considerations on this topic.

B. PENETRATION AID POSSIBILITIES (U)

(U) Of major concern to a TMD system are PENAIDS that might induce a systemic degradation of nonnuclear kill approaches. Some PENAIDS that are implementable with modest changes to a simple system such as Scud fall into this category. For example, tailoring the tank fragmentation process using patterns of shaped charges could create multiple radar and optical targets that could interfere with the radar's ability to discriminate the real target. Dispensing flares could act as a disrupting process for interceptor trackers based on optical or infrared (IR) sensors. Large aerodynamic forces can be created on the warhead by asymmetric fragmentation of the attached missile tank causing it to maneuver in the dense atmosphere.

(U) A commonly cited PENAID approach is the fractionation of the TBM payload into many (presumably too many to intercept) individual warheads. These would be dispensed early in the missile's flight to avoid intercept of the full (undispensed) payload. This would be a stressing penetration tactic if it could be implemented with relatively unsophisticated hardware. The technical sophistication needed, warhead penalties involved, military utility (a question of accuracy and small attacking warheads), usefulness as a weapon of terror, and possible defense responses—among other issues relevant to this approach—need investigation.

C. THEATER MISSILE DEFENSE SYSTEM RESPONSES (U)

(U) The US defense community has a high level of sophistication in both the design of PENAIDS and the corresponding counter-countermeasures. Accordingly, the Task Force is confident that a TMD system can be designed to cope with the PENAIDS that an unsophisticated threat presents and, in effect, drive the threatener to need levels of technology that are beyond its reach. Furthermore, to avoid surprises and to adapt to knowledge obtained by observation—in operation or via intelligence—of potential threats, flexibility in the TMD system software (algorithms, mode variations, etc.) is a necessary attribute.

(U) The earth's atmosphere provides the missile defense with a substantial assist. Radars can detect and measure very small (e.g., 0.1 to .001 g) deceleration of ballistic objects. The air is dense enough at 90-km altitude to begin slowing down very light objects such as balloon decoys and tank fragments. By 60-km altitude, the deceleration of tank fragments may be 1 g or more. Many incidental objects, such as fragments and debris, do not survive to 30-km altitude or take so long to get there that they cause no confusion in the engagement. If, then, the defense can make its intercepts in the vicinity of 30-km altitude, it enjoys a number of important benefits.

(U) • Balloon decoys will have collapsed.

(U) • Chaff will have slowed to very low velocity.

(U) • Tank fragments will have slowed down substantially and can be discarded by the radar processing.

(U) • The atmosphere is still not so dense that heavy objects (i.e., warheads) can begin to maneuver.

(U) • The atmosphere is thin enough to allow favorable HTK intercepts using optical sensors for guidance.

(S) For these reasons, our subsequent discussion of advanced TMD systems will focus on this altitude regime. [redacted]

D. FINDINGS ON PENAIDS (U)

(S) The many years of US R&D in this area puts it in an advantageous position, but some cautions are in order. First, we will not have the detailed technical insight into what PENAIDS theater missile payloads will contain because of the paucity of testing by both the developer and the user. Second, even primitive systems contain surprises as demonstrated in Desert Storm. The US response to the problem of PENAIDS should be [redacted]

VIII. ADVANCED THEATER MISSILE DEFENSE SYSTEMS (U)

(U) Substantial gains in performance are anticipated for the upgraded Patriot. A logical question is whether there is a need for more advanced systems.

A. THE NEED (U)

(U) The Task Force is persuaded that we need to move ahead with R&D on advanced systems for the following reasons:

- (U) More capabable tactical missile threats are very likely to appear in the near future. These may include higher velocity missiles, increasing countermeasures, and more destructive warheads that may be harder to kill than Scud warheads.
- (U) Larger footprints are required against these threats to allow better coverage of targets, less susceptibility to local saturation or exhaustion, and more battlespace to deal with difficult threats and to employ shoot-look-shoot tactics, which permit fewer batteries to be deployed and reduce cost and overhead.
- (U) Improved lethality is needed against these threats and can be achieved with HTK or higher altitude intercepts (improved mission kill).

(C) In summary, the Task Force expects to see a relatively rapid evolution of offensive missile capability over the next 10 years. The [redacted] gives us some idea of what to expect. [redacted]

(S) [redacted]

TABLE 2.—Patriot PAC-3 Forward Footprint Radius: Cuing by SDSP (U)

[redacted]

B. ADVANCED SYSTEM POSSIBILITIES (U)

(U) There seem to be only a few generic approaches for more advanced capability: a more advanced ground-based system, a system relying heavily on space sensing with, perhaps a space-based kill mechanism; and an airborne system using some form of directed energy kill mechanism. Arguments of technological maturity strongly favor the ground-based approach (but with substantial assistance in cuing from space sensors). The SDIO is pursuing an advanced ground-based system, the principal components of which are the TMD-GBR and the THAAD missile. The Task Force believes these components are well matched to the advanced TMD system role.

C. THAAD/GBR (U)

(U) The THAAD/GBR is still a "paper" system with no major system hardware completed. It is envisioned to have the following features:

(U) • TMD-GBR

- (S) — [redacted]
- (S) —

(U) • THAAD

- (U) — High-altitude, HTK missile (smaller than Patriot)
- (S) — [redacted]
- (S) —

(U) • Transportability

(~~C~~) — C-130 compatible
(~~C~~) — Fewer airlift aircraft required than for Patriot

(~~S~~) Figure 3 shows the approximate footprint for the THAAD/GBR and provides a comparison to the Patriot to show that THAAD/GBR is a substantially more capable system. Because we are considering an advanced system, the footprint diagram is drawn for [redacted] The Patriot PAC-3, cued by SDSP, achieves a forward footprint of [redacted] whereas the THAAD/GBR system achieves close to a [redacted] Not shown on the figure is a more difficult threat: The incoming missile velocity is raised to that of the [redacted] The Patriot PAC-3 forward coverage would decrease to [redacted] Thus, it appears that a THAAD/GBR system will be able to sustain a substantial coverage against challenging future threats.

(~~S~~) The outermost contour of figure 3 shows the extensive coverage the THAAD/GBR system could achieve if precision cued by a space system such as BE. (The section on space systems illustrates how they can assist ground-based systems to make them more robust against difficult threats and countermeasures.)

(~~S~~) THAAD is anticipated to make intercepts [redacted] where HTK appears to be an achievable capability. HTK is expected to prove much more lethal than a fragment warhead, but there is not yet sufficient experimental evidence to fully validate this expectation. The Task Force, therefore, recommends [redacted] to serve as a lethality hedge against relatively hard-to-kill warheads or slightly degraded HTK intercepts where the desired aim-point is not hit exactly. A simple calculation of the impact of [redacted]

[redacted]

FIGURE 3.—THAAD/GBR System Footprint Against
600-km-Range Scud Missile
With RCS = 0.01 m^2 (U)

IX. THE NAVY ROLES IN THEATER MISSILE DEFENSE (U)

A. NAVY MISSIONS (U)

(U) The Task Force is convinced that the Navy has important roles to play in TMD. The Navy will be present at most crisis spots and, importantly, it does not need an invitation or the permission of foreign leaders to be there.

(U) One can argue that ships at sea are not very vulnerable to BMs with nonnuclear warheads. However, the Navy has two important missions that force it into defense of more static targets than ships at sea. First, it must defend our ports-of-entry so we can introduce military equipment and personnel into the conflict area. A port under daily attack by chemical weapons will, essentially, come to a grinding halt. Second, the Navy needs to defend amphibious forces as they go ashore and before they are dispersed well enough inland to have some natural protection against chemical warheads. Figure 4 illustrates a tactical missile attack on a Saudi port during Desert Storm. A Scud missile achieved a near miss; if it had hit the ammunition storage area on the end of the pier, the ensuing damage to Navy ships and port operations could have been catastrophic.

B. THE AEGIS SYSTEM (U)

(C) Today there are about [redacted] Their inventory will include thousands of Aegis missiles. Currently, the Aegis system has [redacted] Possibilities for upgrades to Aegis are being addressed in a number of Navy studies. The Navy Research Advisory Council (NRAC) 1991 Summer Study was a key study, which—not surprisingly—found that Aegis (like Patriot) can be upgraded to have a substantially improved TMD capability. The Task Force agrees and recommends that the system be upgraded to perform the conventional Navy missions of

- Defense of shics and task forces,
- Defense of ports, and
- Defense of amphibious operations.

(U) The Task Force is convinced that the Navy can play a larger role, one that goes beyond its traditional missions. The role we envision is using ship-borne systems to provide *regional* TMD by creating a defense envelope that would extend many hundreds of kilometers around the ship. Such a defense would require new interceptor missiles, new radars, and a strong reliance on space sensors for warning *and* cuing.

(U) The Navy possesses the unique ability to provide defenses in a threatened region before diplomatic negotiations have provided the strategic access necessary to deploy land-based defenses. Indeed, in a crisis, the protection offered by ship-borne defenses may be critical in gaining the cooperation of potential coalition partners and inducing them to grant the access to their territories required for land-based forces. Ship-borne capabilities also may be critical in defending against attacks on ports and airfields that could disrupt the vulnerable early stages of a deployment until the defensive mission can be assumed by land-based systems. This broader regional mission creates a requirement for advanced defensive capabilities not only to meet future threats but also to provide extended the footprints necessary to protect allied territory and US forces inland.

[redacted]

FIGURE 4.—Scud Missile Attack on Pier at Jubayl (Saudi Arabia)
16 FEB 91 (0205 Local Time) (U)

X. SPACE SYSTEM CONTRIBUTIONS (U)

A. STEREO DSP, BRILLIANT EYES, BRILLIANT PEBBLES (U)

(U) The Task Force was impressed with the variety of contributions that space systems can make to TMD. Table 3 shows the breadth of the potential contributions from three space systems: SDSP, BE, and BP. (As noted earlier, the Task Force considered FEWS to be the follow-on to the DSP system; therefore, "DSP" is used to mean not only the existing system but FEWS as well.

(U) The SDSP system uses two DSP spacecraft to view a launch event to improve the metric accuracy of the tracking and trajectory prediction. BE is a distributed satellite system that will use IR sensors to track threat missile from launch through midcourse and reentry. It will use three IR sensors: a short-wavelength sensor to track the missile during burning, a mid-wavelength sensor to track upper stage burning, and a longer wavelength sensor to track the warm reentry vehicle during the midcourse phase of flight. The BE satellites would be deployed at 1600-km to 1700-km altitude and be deployed in an initial constellation of 18 satellites.

(U) BP is a space-based intercept system that would kill an enemy missile during its boost phase. It would work best against the longer range threats such as the CSS-2 missile and would not work very well against the shortest range tactical missiles. The Task Force considers BP to be a more distant TMD element than is the THAAD/GBR system.

TABLE 3.—Space System Contributions to TMD (U)

	SDSP	BE	BP
Alerting	X	X	
Launch Point Location	X	X	
Radar Cuing	X	X	
Threat Intelligence		X	
Discrimination		X	
Midcourse Interceptor Control*		X	
Space Intercept*		X	X

*Treaty concern

UNCLASSIFIED

(U) The first contribution of space systems is "alerting," that is recognizing that a missile has been launched and sending a message used to turn on radars and warn personnel. This is a most important function because it is impractical and inefficient to maintain TMD systems such as Patriot and THAAD/GBR in a continual state of full readiness and full surveillance operation.

(S) Space systems have the unique ability to provide an accurate and prompt determination of launch point. With SDSP data, the launch can be determined within [redacted] This location information can be used to identify the attacker, perhaps classify the attacking missile, and importantly, allow us to strike back (counterforce) quickly at the launch vehicle or facility.

(U) The benefit of cuing the radar was demonstrated in the discussion of system footprints. Under uncued operation, the GBR searches a relatively large threat volume and, when the incoming object is detected, tracks it for eventual intercept. Space systems, by providing early launch detection, launch point location, and (initially) crude trajectory information, can allow the cued radar to search a much smaller threat volume and, thereby, detect the threatening objects at substantially longer ranges. This leads to the much larger areas that can be defended, as illustrated in figures 1 and 3.

(U) Threat intelligence would be an important benefit of the BE space system. Recall the earlier concern that we might not have complete intelligence on TBM threat specifics because of the lack of testing by the developer and the user. If untested missiles were being used in a war in which we were not involved (e.g., the Iran-Iraq War, the conflict in Afghanistan), a substantial satellite constellation such as BE could collect unique and valuable intelligence data on those missiles.

(U) Another potential benefit of space systems is discrimination. The multispectral IR capability of a BE satellite will allow it to contribute to discrimination of threat objects from non-threat objects such as balloon decoys or fragments originating from the intentional breakup of the missile rocket body. Decoys, fragments, and other PENAIDS can cause substantial confusion to GBRs during the exoatmospheric phase of the missile flight. The combination of radar and IR sensor data can be a powerful approach to mitigating this confusion. IR optical viewing of the threat complex is also a powerful tool for overcoming electronic jamming attacks on the GBR.

(C) The last two potential contributions to TMD of space systems shown in table 3 involve those systems more directly in the intercept of the threat missiles. [redacted] Midcourse interceptor control commits a ground-based interceptor based on BE's detection and tracking of the threat. In one scenario, the ground radar may be involved prior to intercept to direct the interceptor; the interceptor acquires the target and makes the kill. However, the ground radar may not need to be involved at all if the space information is sufficient to direct the interceptor's acquisition of the target for final tracking and kill. This mode of operation produces the largest footprints possible for ground-based interceptors—reaching to the kinematic limits of the interceptor [redacted] Finally, the space-intercept approach may use the BP space-based intercept capability to conduct the entire engagement leading to an "on-station" capability in space with, essentially, global footprints.

B. FINDINGS ON SPACE SYSTEMS (U)

(S) The Task Force recognizes that space systems can provide many contributions to TMD. Some of these, such as alerting, are essential to the successful operation of any ground-based system; most others provide enhanced capability to the ground system in such areas as coverage and resistance to countermeasures.

The Task Force recommends that the SDSP capability be implemented in the near term. Our understanding is that this capability can be available in the 1994 time frame and involves mainly ground hardware and software changes rather than expensive spacecraft changes.

(U) The Task Force believes that the BE capability should be pursued with an R&D program leading to the minimum experiment in space needed for a demonstration.

(U) The Task Force has no recommendation on BP as a separate TMD entity. The Task Force notes, however, the attractiveness of its "on-station," instant-defense capability and its utility as an outer layer defense against long-range TBMs.

XI. MANAGEMENT ISSUES (U)

(U) In Desert Storm, the Patriot system performed well against the modified Iraqi Scud missiles. However, the Patriot was clearly at the limit of its capability against that threat in a number of respects. Therefore, the Task Force has a sense of urgency in moving on with improved TMD systems. The first of these is the further upgrade of Patriot, and the Task Force recommends the Army's upgrade schedule be accelerated. But the Task Force's sense of urgency does not stop with Patriot upgrades. More stressing threats than the modified Scuds exist within the Chinese, Soviet, and (perhaps) North Korean inventories and could be transferred to hostile regimes at any time. Therefore, the Task Force argues that we move ahead at a rapid pace with the THAAD/GBR system to obtain the advanced capabilities it can provide.

(U) Importantly, there is agreement on what needs to be done (e.g., upgrade Patriot and Aegis, develop THAAD/GBR, upgrade space sensors, and develop new space systems). However, there is no consensus on the pace of the pursuit of these capabilities, and the appropriate organizational structure may not be in place for the major TMD system effort required for a near-term system deployment.

(U) The Task Forces's investigation of TMD convinces us that TMD is an important *National* mission that will use systems from all the Services. The Army is involved via Patriot and will likely be involved through the advanced THAAD/GBR. The Task Force urges strong Navy involvement via Aegis upgrades and a regional TMD capability. The Air Force is involved through the important space systems such as DSP and BE. Thus, TMD is very much a *joint* Service and SDIO activity. *We need a management plan for that National, joint activity.*

(U) If there is to be a rapid push toward fielding new capabilities, we must determine who is to integrate and manage the effort. Such activities are not in the charter of the SDIO. That charter limits the SDIO to R&D with a budget limited to 6.1, 6.2, and 6.3A funds. The SDIO staff is not selected for experience in the integration and management of a major acquisition and fielding exercise. If the SDIO is to play the lead role in this area, its charter needs to be amended, its structure modified, and its staff selected to reflect these new responsibilities.

(U) With regard to the pace of our efforts, there is a lack of consensus among the SDIO, OSD staff, and the Services on how fast we need to move on the development of an advanced TMD system (i.e., THAAD/GBR). The SDIO interprets statements by the President and the Secretary of Defense concerning a substantially improved TMD capability in 1995 as cause to move rapidly on the THAAD/GBR Program. OSD staff are not seized with the same sense of urgency and seem to favor a more temperate pace. The Task Force believes there is enough ambiguity in the statements to justify both views. The Secretary of Defense can resolve the ambiguity by clearly stating what the DoD pace is to be. The Task Force's view on this issue is that we should develop the THAAD/GBR system (and upgrade the Patriot system) at as brisk a pace as does not cause substantial risk. This pace may be somewhat slower than the SDIO proposes, but it is not nearly as slow as the "business as usual" DoD procurement process. Therefore, we foresee the need for some accommodation in the development/procurement process to permit a more rapid pace.

(U) The last management issue is individual Service reluctance to move aggressively into TMD. We think this reluctance is due simply to the extreme concern with declining budgets and force levels. ("If we get involved, will we get stuck with the bill in future years?") Strong Service involvement will be required to move us to the level of TMD capability needed for the future. The Secretary of Defense needs to clarify the roles of the Services and the SDIO in this new mission area and address their concerns about funding.

XII. "BOTTOM LINES"— OUR RECOMMENDATIONS ON THEATER MISSILE DEFENSE (U)

(U) The recommendations of the Task Force are summarized below.

(S) • The Patriot upgrades are sensible—make them quickly. Support and fund the PAC-3 modifications and accelerate the schedule to provide full capability (rather than the planned Initial Operating Capability) in [redacted]

(S) • The Navy should upgrade Aegis to have a significant TMD capability. The Navy should also adopt a substantial role in regional TMD.

(S) • The growing capability of tactical threat missiles requires new, advanced, active defense systems. The THAAD/GBR system appears well matched to meet this growing threat. Therefore, continue aggressive R&D on the THAAD/GBR system.

- (C) [redacted] of the defensive warhead is a critical pacing item. DoD should support a substantial [redacted] In the meantime, our interceptor warhead developments should include a substantial weight and volume hedge for possible [redacted] devices or techniques.

- (S) Space systems provide essential cuing, countermeasure resistance, and tactical missile intelligence to all TMD systems. Therefore, we should

  - implement SDSP processing for tactical missiles and
  - aggressively pursue R&D on BE, leading to the minimum experiment needed to demonstrate its capability.

- (S) [redacted]

- (S) The Secretary of Defense should provide a common understanding of

  - the priority and urgency of TMD R&D and system implementation and
  - Service implementation roles and budgets.

(U) These recommendations are not necessarily listed in priority order, but the Task Force clearly believes that the number one priority is the Patriot upgrade followed closely by the Navy's adoption of a more substantial TMD role. After these two recommendations, the Task Force members would argue as to what is the next priority. There is no argument, however, that *all* these recommendations are needed to build a robust National TMD capability.

Appendix A (U)

TERMS OF REFERENCE (U)

TERMS OF REFERENCE (U)

(U) Over the past thirty years ballistic missile defense (BMD) issues have been debated within DoD and have been studied at length by task forces of the Defense Science Board, the Defense Policy Board and others. The initiation of the SDI Program in 1983 substantially increased the impetus and prominence of BMD research and development. During this period, for the first time, the JCS established a requirement for a strategic defense system to deter and counter the Soviet offensive arsenal. While no system has entered full scale development, substantial progress by the SDIO has been made over a wide technological dimension. In recent years the proliferation of ballistic missiles and weapons of mass destruction has heightened interest in a capability for global protection against such threats including the defense of deployed and deployable forces and the territories of our allies. The DSB, in its 1990 Summer Study recommended a defense option for a "light" defense of the U.S. to be effective against similar threats. Finally, the recent Desert Storm experience with Patriot has highlighted some of the values and limitations of a deployable ATBM capability.

(U) As part of the 1991 DSB Summer Study you are requested to organize a Joint DSB/DPB Task Force on Ballistic Missile Defense to consider the requirements for tactical and theater ballistic missile defenses; their interaction and interfaces with CONUS BMD; recommendations for development and deployment options; the necessary technological underpinning; ABM Treaty implications and other related policy issues.

(U) The Task Force should establish liaison with appropriate organizations including OUSD(P), OASD(ISP), OASD (C3I), Joint Staff, DARPA, SDIO, the Services and others as required. The Task Force should be prepared to provide "quick reaction" advice and recommendations to DoD officials upon appropriate request.

(U) It is expected that the Task Force will address issues and make recommendations on topics including:

(U) — What is the time phased spectrum of ballistic threats likely to face deployed tactical forces considering technical characteristics, numbers and operational capabilities? What countries are likely to achieve a ballistic missile capability? What generic strategic and tactical situations are deployed forces likely to encounter?

(U) — As threats proliferate and become increasingly sophisticated, what are the most likely circumstances under which the U.S. could expect a ballistic missile attack on CONUS deployed forces or allies. How should U.S. programs be structured to permit us to respond?

(U) — What are the system and subsystem options and their availability as a function of time for theater BMD? What are the lethality requirements? What is the required technological base.

(U) — What should be the relation between theater ballistic missile defense and "light" defense of the U.S. (e.g., Global Protection Against Limited Strikes [GPALS])? Between TBMD and air defense, Tactical Warning/Attack Assessment (TW/AA), tactical reconnaissance?

(U) — What role would be desirable for friends and allies in the development, production and funding of a TBMD? What role might they play in the deployment and employment of such a system?

(U) — What policy options are available to allow allies to participate in the cost and development of technologies and still provide adequate protection for U.S. technology?

(U) — What lessons were learned in the Gulf War concerning BMD?

(U) — How may ABM Treaty restrictions on strategic defenses affect the development and deployment of TBMD capability? If Treaty restrictions constrain such efforts, what policy or technological options are available to permit them to proceed?

(U) — What would be the resource requirements associated with any proposed TBMD system?

(U) — What associated needs might be raised by alternative proposed TBMD systems (e.g., requirements for transport for rapid overseas deployment)?

(U) The Deputy Assistant Secretary of Defense Strategic Defense, Space Verification and Policy (ISP), the Deputy Directors of Defense Research and Engineering for Tactical Warfare Programs and for Strategic and Theater Nuclear Forces, and the Director of the Strategic Defense Initiative Organization will sponsor this Task Force. Mr. Daniel Fink and Mr. Fred S. Hoffman will serve as Co-Chairmen. Mr. Daniel Goure, PDUSDP (S&R), will be the Executive Secretary and Col Elray Whitehouse, USA, will be the DSB Secretariat representative. It is not anticipated that your inquiry will go into any "particular matters" within the meaning of Section 208 of Title 18, U.S. Code.

Appendix B (U)

HOW MUCH FOOTPRINT IS NEEDED IN A TMD SYSTEM? (U)

Daniel Shoham
M.I.T., Lincoln Laboratory

HOW MUCH FOOTPRINT IS NEEDED IN A TMD SYSTEM? (U)

(U) How much footprint is needed to cover typical targets is a question raised by the Task Force. A short and approximate anaylsis* was performed to gain some initial insight on the question. The assumption was made that the dominant factor in determining the necessary footprint size would be the defense of urban population rather than the defense of fixed military targets or military forces in the field. Therefore, this appendix focuses exclusively on defense of urban populations.

(U) Protection of a given percentage of the urban population of a geographical region is a reasonable defense goal. The protection provided by any theater missile defense (TMD) system footprint will depend on the particular geographic distribution of the population. To create a geographical database, we assembled information on fifteen regions.

- England and Wales
- Florida
- Greece
- Italy
- Japan
- South California
- Texas
- Saudi Arabia
- Bangladesh
- Egypt
- Israel
- Pakistan
- South Korea
- Sri Lanka
- Taiwan

(U) For each region, we listed all cities with populations above a given threshold (usually 5,000). Latitude and longitude for each city were determined. For each region, the population distribution was analyzed. Figures B1a and B1b show, as an example, the population-distribution analysis for South Korea. Figure B1a shows how 75% of the urban population of South Korea could be defended by systems with 30-km footprints and 100-km footprints. Figure B1b shows the number TMD systems needed to achieve the defense goal (percentage of population to be defended) as a function of footprint size. Similar analyses were performed for the other regions in the study. Figures B2a-B2d compare the results of the studies for South Korea with those of Saudi Arabia, Italy, and Israel.

(U) Because of the large distances between its relatively compact population centers, a country such as Saudi Arabia is probably best defended with a number of TMD systems with relatively small footprints. Israel, on the other hand, can be defended well with one TMD system with a footprint radius of approximately 100 km. Countries with relatively dense populations spread over extended areas (e.g., Italy, Japan) would benefit from systems with large footprints. Less urbanized Third World countries are, perhaps, best defended by systems with intermediate footprints. Generally, the Task Force believes that new TMD systems should strive for footprint radii in the 100- to 200-km range to permit them to defend a variety of targets.

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* (U) Shoham, Daniel, *Defense of Urban Population With Anti-Tactical Missiles: Footprint Considerations*, MIT Lincoln Laboratory report to be published.

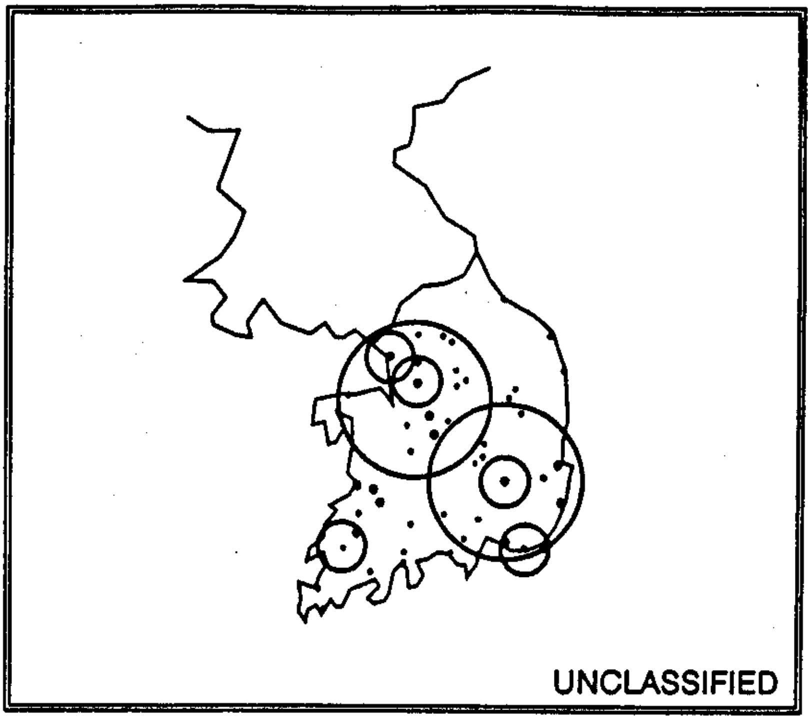

FIGURE B1a.—Defense of 75% of the Urban Population of South Korea With 30- and 100-km Footprint Systems (U)

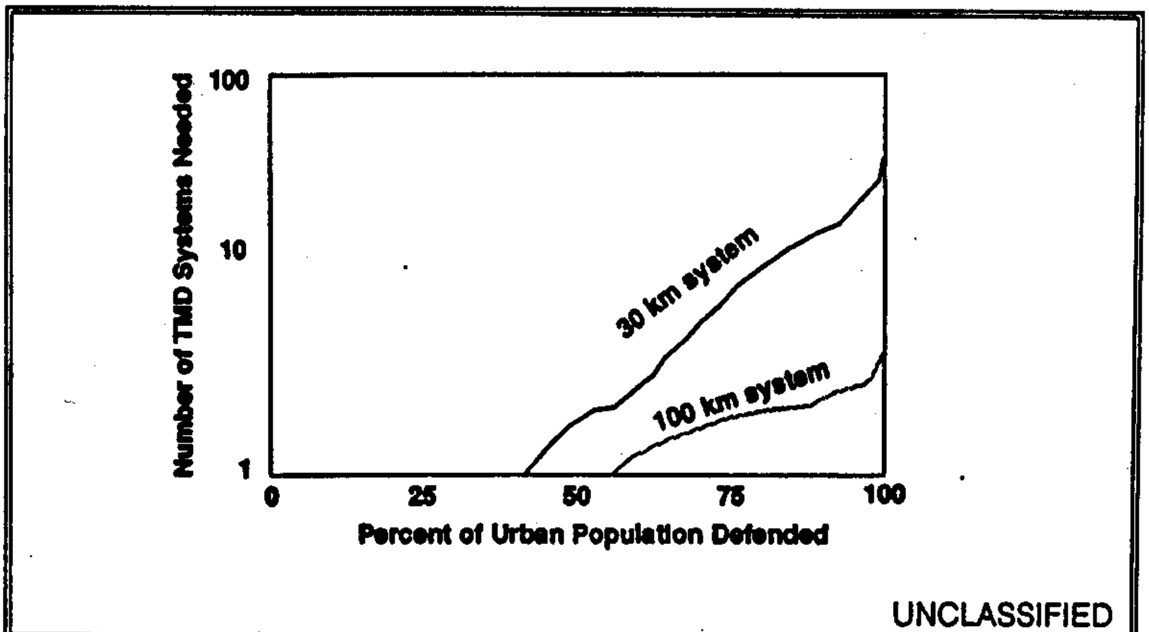

FIGURE B1b.—Percent of Urban Population of South Korea Defended as a Function of Footprint Size and Number of TMD Systems (U)

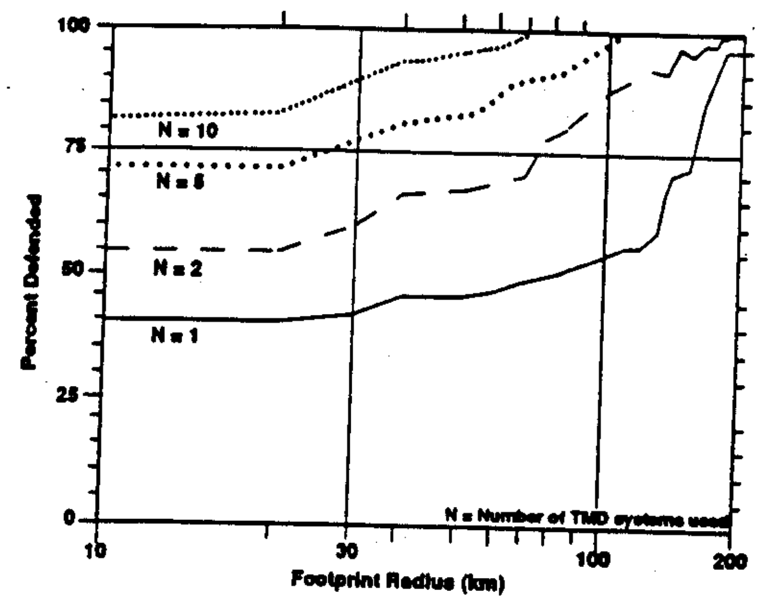

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FIGURE B2a.—Percent of Urban Population of South Korea Defended as a Function of Footprint Size and Number of TMD Systems (U)

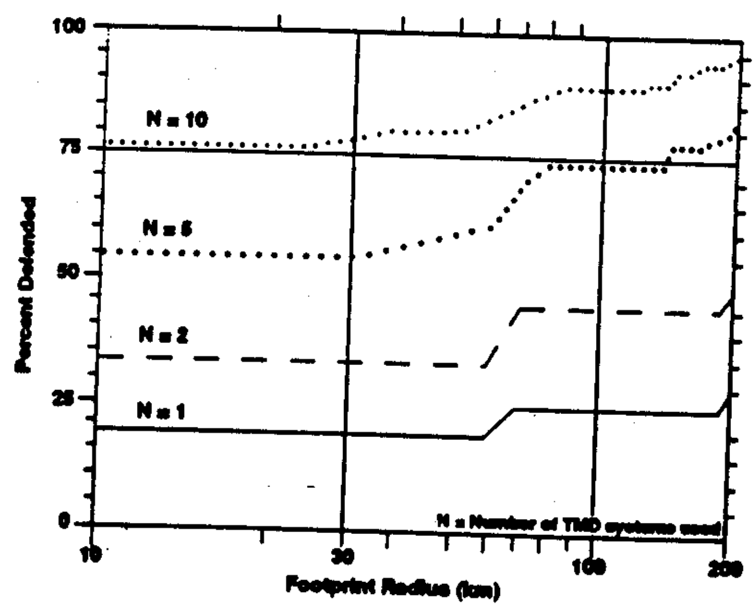

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FIGURE B2b.—Percent of Urban Population of Saudi Arabia Defended as a Function of Footprint Size and Number of TMD Systems (U)

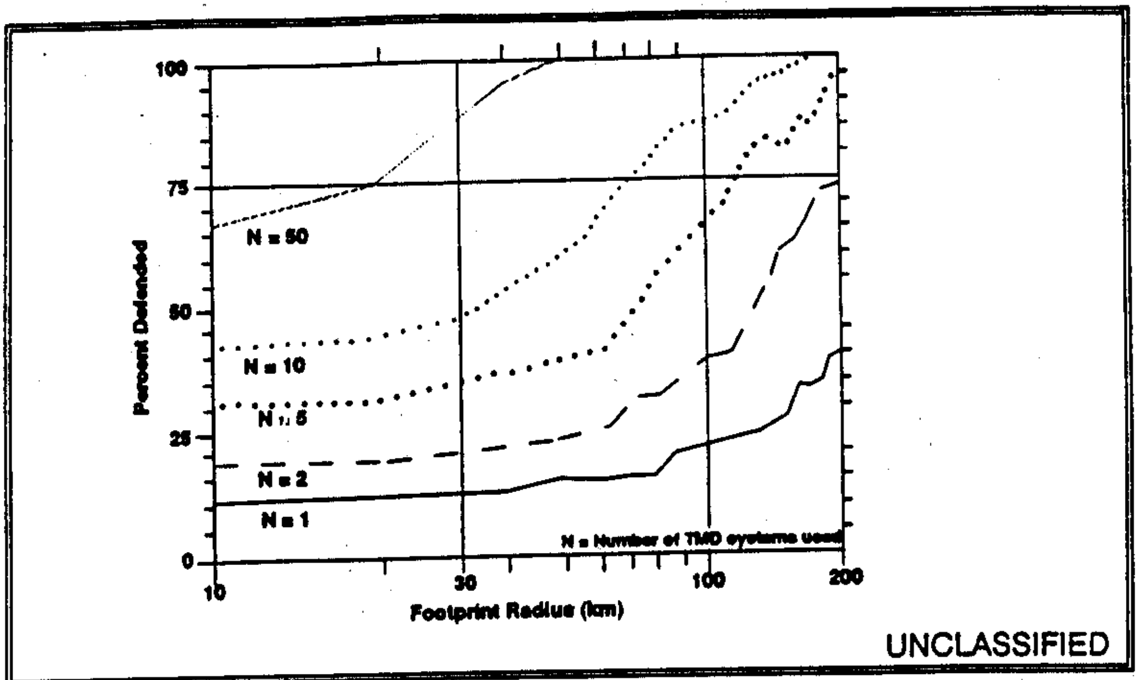

FIGURE B2c.—Percent of Urban Population of Italy Defended as a Function of Footprint Size and Number of TMD Systems (U)

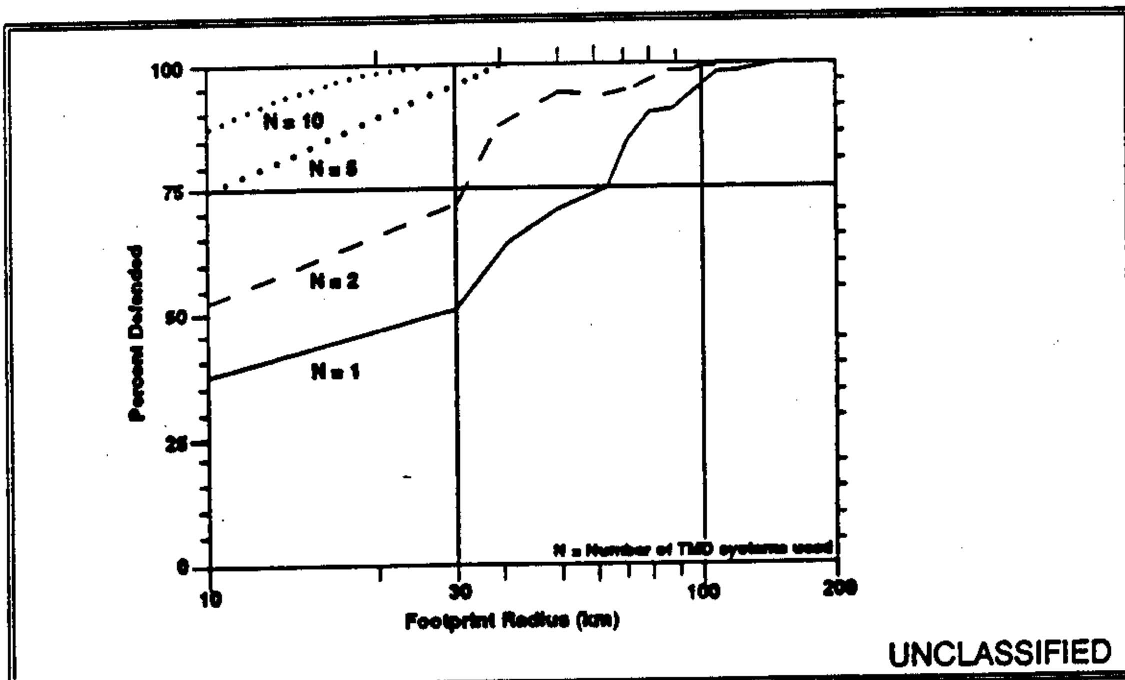

FIGURE B2d.—Percent of Urban Population of Israel Defended as a Function of Footprint Size and Number of TMD Systems (U)

(U) One cautionary note is that the TMD system footprint is only one consideration in the design or the evaluation of the system. Some of the other factors that must be considered are lethality of the defensive warhead, countermeasure resistance, available battlespace, and the role of cuing sensors.

Appendix C (U)

LETHALITY OF TMD WARHEADS (U)

M. Atkins (SAIC), J. Beyster (SAIC), J. Braddock (BDM), K. Bradley (DNA), P. Castelberry (DNA), C. Smith (SAIC)

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I. LETHALITY OF TMD WARHEADS (U)

A. INTRODUCTION (U)

(U) The Defense Science Board/Defense Policy Board Task Force on Theater Missile Defense (TMD) heard a number of presentations on warhead lethality issues during the spring and summer of 1991. In addition, the Task Force received a collection of reports and the results of current research. In this summary report, we present observations on the status of this critical and complex field, and we include some recommendations for further work. Although much lethality work has been performed, TMD programs must use old, perhaps outdated, information, much of which was acquired for purposes other than TMD. Many data (experimental and test) are available on which to base conclusions. There are some differences of opinion among those working in the area of lethality; so the conclusions and recommendations offered here may well be controversial. If so, the Task Force hopes its statements will focus efforts and lead to the timely resolution of key issues.

(U) Traditionally, lethality has been a well-defined quantity used in missile defense technology to describe probability of a hard kill (P_k) of an incoming ballistic missile given an intercept. In addition to hard kill, one can expect situations where the TMD interceptor does not destroy the incoming warhead or missile but diverts it from its intended target, i.e., mission kill. Further, the real-life situation in which the TBM warhead and the attached missile parts may not be completely destroyed so that the potential for collateral damage exists should be considered in TMD lethality studies. In view of the Desert Storm experience, we have taken the liberty of a including mission kill and collatral damage isues in our deliberations. We also include a brief discussion of those factors we believe are important to effective tactical ballistic missile (TBM) intercepts.

B. BACKGROUND (U)

(U) The question of interceptor lethality—the ability of a defensive system that performs properly in all other respects to produce the requisite damage to the incoming warhead—has always been a substantial part of antiballistic missile (ABM) programs. In the Safeguard days, flight tests and underground nuclear tests were executed to validate lethality of the two interceptors. At the beginning of the Strategic Defense Initiative (SDI), the SDI Organization (SDIO) designated the Defense Nuclear Agency (DNA) as its single manager for research on lethality of all types of weapons under consideration. DNA has executed the Lethality Program, in part, through the appropriate laboratories and R&D centers of the Services. DNA coordinated its SDIO-funded work with its own applicable on-going programs and has adjusted the level-of-effort devoted to lethality of the various types of defensive weapons to program demands. Although there is substantial, critical technical work remaining to be done, there is now a rich background of technical knowledge and experience that ties weapons-effect research closely to the intelligence community and to defense system development.

(U) Despite the quantity and quality of work performed on ABM lethality, the Task Force found that there are significant gaps in the knowledge needed to support design of TMD systems. The amount of effort devoted specifically to TMD was relatively small until the current fiscal year, and it will not approach an adequate level until next fiscal year.

(U) It is necessary to provide some of the reasons why the answers needed for TMD cannot be found in the knowledge base that has been accumulated. The most important of these reasons is that, essentially, all prior work focused on intercepting strategic reentry vehicles (RVs) carrying nuclear warheads. While a nuclear warhead and its associated equipment are not necessarily fragile assemblies, their successful operation depends on proper functioning of a number of complex but well-understood components. Unless everything happens just right, there is no nuclear yield, and the intercept has been successful if it disrupts any of those components. (This may not be strictly true, but in the context of an SIOP exchange, it is a reasonable approximation.)

(U) TMD systems, however, will face a variety of warheads—high explosive (HE), incendiary, nuclear, biological and chemical—with the possibility that any of these (except nuclear) may be contained in submunitions. Intercept of a biological warfare (BW) or chemical warfare (CW) weapon, which consists of a large tank of agent (called a "unitary-fill" or "bulk-release" device) inside a reentry shield, involves some very trick lethality problems. Unlike a complex nuclear or HE weapon, the agents are ready to work when released from their tanks. The intercept may actually perform part of the attacker's job for it by spreading the agent around—if not on the intended target then perhaps on an equally important friendly or neutral location. However, if the intercept occurs at a sufficiently high altitude, laboratory tests show that a chemical agent will be dispersed enough to be innocuous; this intercept altitude corresponds to realistic keep-out altitude requirements for ground-based interceptors being considered by the Army. At this time, however, knowledge of BW agent dispersal has not been developed.

(U) Lethality against TBMs carrying submunitions of any type involves new considerations for the defense community. The submunitions shield each other and may be very hard so that a massive kinetic energy impact (or other equivalent intercept event) may be needed to provide assurance of killing all or a significant fraction of the submunitions.

(U) Compounding these problems, of course, is the need for the TMD designer to provide a single interceptor that will provide acceptable P_k against any of the potential threat warheads because the defense operator may not know which type of warhead he is countering. While the research programs eventually will lead to optimized intercepts against each type of warhead, it is far too early to know how to design a "general purpose" interceptor.

(U) Thus far, we have discussed the TMD-unique lethality problems posed by the variety of warheads that may be encountered. Another factor that complicates the problem is that TBM trajectories are so low that the intercepts may take place at such low altitudes that aerothermal heating will not cause effective destruction of the TBM payload as happens in strategic encounters.

(U) DNA and the US Army Strategic Defense Command (USASDC), which is executing much of the TMD Lethality Program, have responded with a research program involving a roughly appropriate mix of theory, laboratory experiments needed to understand the phenomena, and large-scale field trials. One caution that we would give is to proceed at a measured pace with extensive field tests, ensuring that they are focused on real information needs and that diagnostics are adequate to make the results quantitatively useful to warhead designers. This will be no small task because there are a number of weapon systems requiring data in a timely manner.

C. THREAT AND LEAKAGE CRITERIA (U)

(U) As shown in table C1, the warhead threat from TBMs can take many forms—conventional, conventional submunitions, biological submunitions, chemical unitary, chemical submunitions, and nuclear. Countries having TBMs are shown in figure C1, and those possibly having chemical capability are shown in table C2. Assessments of on-going activities suggest that most Arab nations, India, and Pakistan have spray tank and bomb versions of liquid chemical agents and may upgrade these to dry agents in the next 5 years. A number of Arab nations, China, and Israel probably have bulk warheads for ballistic missiles and may incorporate submunitions in the next 5 years. BW toxins could be advanced along the same lines. Genetic engineering of toxins, as well as microencapsulation, could take 10 to 20 years.

(S) Illustrative of the simple technology that Third World countries could employ to develop CW weapons is a rough design study performed by MSIC [redacted]

TABLE C1.—Lethality Threat (U)

PAYLOAD:	100 kg to	500 kg
CEP:	100 m to	3,000 m
USE:	MILITARY (small target)	POPULATION (large-area target)

TYPE	DETAILS
Conventional	
Unitary	High Explosive
Enhanced	Aluminum Shell + High Explosive
Standard Submunitions	Anti-material Munition
Hard Submunitions	Runway Penetrator
Chemical	
Unitary	Bulk Chemical Agent Dispersed During Terminal Flight
Submunitions	Hard or Soft Bomblets Patterned Dispersed Agent Dispensed on Impact
Biological	
Submunitions	Hard or Soft Bomblets
Nuclear	
Single/Multiple	Implosion Type
Hardened	Gun or Earth Penetrator

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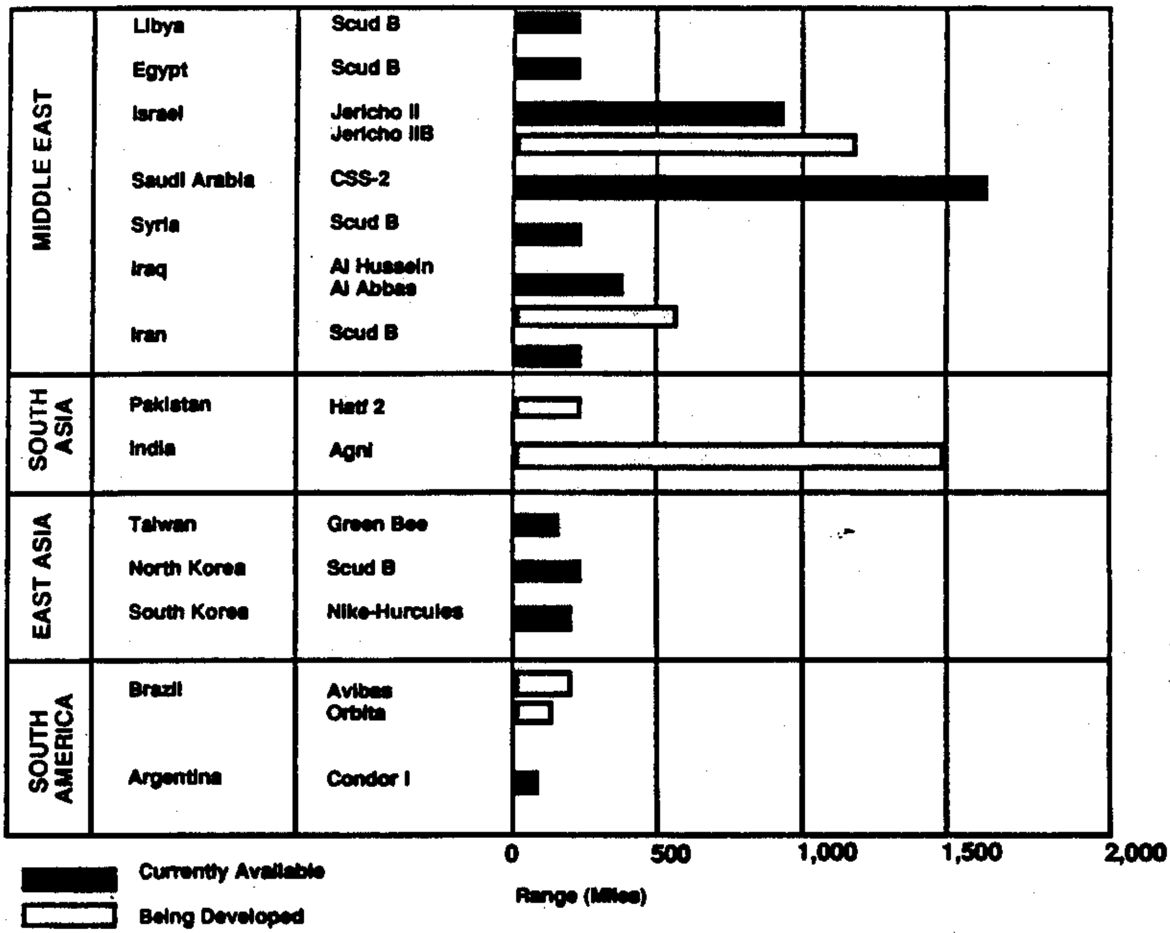
(U) Submunition warheads are a significant issue for TMD lethality. They are neither new nor high technology. For illustrative purposes, an obsolete and unclassified US chemical submunitions warhead (Honest John) is shown in figure C2. This was a tactical system, weighing about 560 kg. Before the Honest John was demilitarized (over 10 years ago), tests of agent rain from vehicles deliberately damaged at between 400- and 900-meters altitude were made. These tests showed that most of the agent released in an intercept contaminated the ground at hazardous levels.

(U) The Honest John was a tactical missile system with warhead configurations that included a payload of 368 M139-bomblets. In normal operation, the submunitions were explosively dispersed at altitude and impact about their center of mass to the target area. Each bomblet was about the size of a softball and contained 0.6 kg of nerve agent and a 0.07-kg Comp-B burster charge for agent dispersal. The bomblet illustrated had vanes, which caused it to spin between 1200 and 1800 rpm and functioned on impact with the ground. Each of the submunitions could contaminate a circular area with a 25-m diameter to a lethal level. The contents of the warhead could target an area on the order of 1-square km.



Source: "Third World Ballistic Missiles." *Scientific American*, August 1990.

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FIGURE C1.— A Survey of Third World Ballistic Missiles (U)

(U) Complete destruction of even this obsolete warhead is challenging to current lethality concepts. Test data indicate the number of defeated bomblets for submunition-type warheads may be as high as 70%. Very energetic collisions are necessary to reduce the effectiveness of the submunition-configured tactical chemical warhead, particularly because other CW munitions have been built that are much more rugged than those of Honest John. More than kinetic energy may be required for a practical and effective defense. It is not clear that just hitting these submunitions with a pellet or fragment would cause them to arm and disperse the agent prematurely. This example shows the technologies that may be readily available to those in the Third World designing new TMD systems. A chemical or biological submunition attack is a probably a real and a stressing threat to TMD systems today. Such attacks would undoubtedly be considered major escalations of a conflict and akin to terrorist attacks; our response would not necessarily be constrained to shooting down these warheads. However, it is important to have as much capability as possible to do so in improved TMD systems.

TABLE C2.—Proliferation of Chemical Weapons in the Third World (U)

KNOWN*	PROBABLE**	POSSIBLE†	DOUBTFUL‡
Iraq	Burma	Angola	Afghanistan
Iran	China	Argentina	Chad
Egypt	Ethiopia	Cuba	Chile
	Israel	India	El Salvador
	Libya	Indonesia	Guatemala
	N. Korea	Laos	Jordan
	Syria	Pakistan	Mozambique
	Taiwan	Somalia	Nicaragua
	Vietnam	S. Africa	Peru
		S. Korea	Philippines
		Thailand	Sudan

(U) *Countries in this column are either those that have declared that they possess chemical weapons or whose use of such weapons has been definitely confirmed.

(U) **Countries listed as "probable" are those reported by US Government officials, on the record, as developing, producing, or possessing chemical weapons.

(U) †Countries in this column are those reported by Western Government officials, generally off-the-record, as seeking to acquire chemical weapons or chemical weapon production capabilities or as suspected of possessing chemical weapons.

(U) ‡Countries listed as "doubtful" are those reported, generally by domestic or foreign adversaries, as seeking to possess, possessing, or using chemical weapons but for which there is no confirmation by Western Government officials.

Source: *Chemical Weapons Posture in 1985.* UNCLASSIFIED

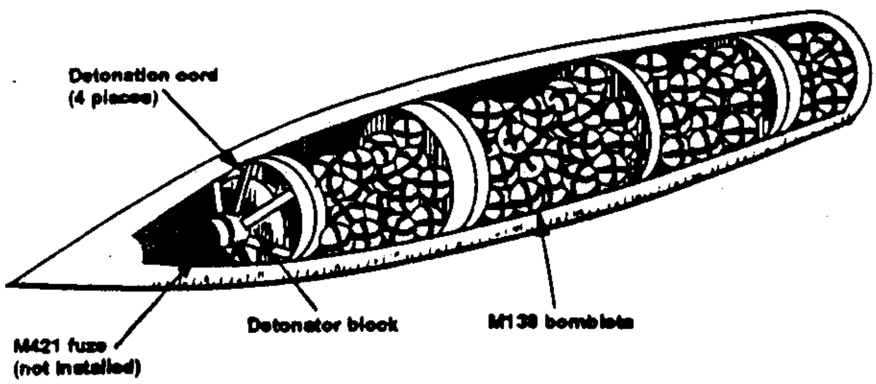

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FIGURE C2.—Honest John M190 Warhead

(U) It is thought provoking to attempt to define the spectrum of threat RVs a defense must be prepared to counter in the future. Leaders in the lethality community have always recognized that they must not define threats too specifically because even should they have perfect intelligence on some existing threat vehicles, the threat will change during the lifetime of the defense system. At the same time, for many purposes, it is necessary to define some threat objects fairly specifically so calculations can be made and experiments can be performed. When considering the Soviet nuclear threat, the tendency has been to mirror-image, then perturb that image—including the time scale—with intelligence data when possible. In the TMD problem, researchers must plan against threats to which the United States may have no counterpart, that are designed and produced by unknown future adversaries, and that have unknown capabilities. They may be obtained—and employed—to meet perceived requirements that the United States may not understand well. In addition, potential Third World adversaries tend not to test; therefore, intelligence data may be sparse. At best, this situation will cause the researchers to consider a wider spectrum of possible threats, making their work more broadly applicable.

D. LEAKAGE CRITERIA

(U) Acceptable warhead lethality for a given TMD system depends on the leakage that can be tolerated at the defended position. For that reason, the Task Force thought it advisable to make some remarks on leakage criteria in the context of TMD. The performance of active TMD systems against a threat can be characterized by their robustness to causes types of system failures. These include defense suppression, exhaustion, and saturation. Defense suppression attacks are directed against the elements of the defense system. We will not discuss such attacks. Leakage due to exhaustion occurs when the defense runs out of interceptors.

Leakage due to saturation is caused when the system's traffic-handling capabilities are exceeded (there are too many threat objects to handle at one time). In addition to leakage from exhaustion and leakage from saturation, system leakage can occur as the result of failure to detect or discriminate threat missiles, failure to intercept after detection, or failure to kill even when an intercept has occurred.

(U) Acceptable levels of missile leakage depend upon the consequences of that leakage: 1) damage to population centers and 2) damage to military targets. In most scenarios, minimal defenses are available for an attack against population centers; thus minimal leakage is important. Successful attacks against population centers can trigger retaliation against the aggressor by the country attacked or one of its allies; this retaliation may be an unwanted escalation and, therefore, low-leakage defense is doubly important. More than one tier of defense may be needed to achieve such low leakage to protect civilians. In the case of TBM attacks on military forces, low leakage is a desirable, but not as critical, because the military forces presumably are engaged or on alert and are better protected. Thus, higher leakage can be tolerated for the defense system.

(S) Meeting these leakage criteria is not straightforward because some of the variables affecting leakage are not controllable by the defender. The numerical size, geographical focus, type of warheads, and salvo timing, for example, are determined by those launching the TBMs. What might be a relatively low-leakage defense for a limited attack could easily become a high-leakage defense through saturation or exhaustion. Thus, attainable leakage values are scenario-dependent. For example, [redacted]

(U) The larger footprints afforded by the various Patriot upgrades—QRP, QRM, PAC-3, cuing—effectively increase robustness against saturation by offering the possibility of overlapping defense coverage if supported by appropriate battle management. Compared to the PAC-2, an autonomous PAC-3 or a cued QRM PAC-2 provides almost an order-of-magnitude increase in defended area against the Al Hussein-type threat. A cued PAC-3 may offer another factor-of-four increase in defended area. Thus, a given area may be defended with a smaller number of batteries, and the batteries will still have an increased tolerance to saturation.

(U) In addition to the above factors, one must consider the significance of where the leaking warhead impacts. All locations in an urban area or military target are not of equal value, and the political and military consequences of destruction vary from none to very serious. No active defense TMD system alone can guarantee low leakage against a massively focused attack. The use of counterforce (for example, scatterable mines in launch areas, air attacks on non-active launchers, and—eventually—boost-phase attacks on launchers) to disrupt and constrain such attacks was attempted in Desert Storm to limit the size and duration of attacks. While our offensive actions against Iraqi launchers and missiles may not be credited with many kills, there is persuasive circumstantial evidence that they helped prevent the type of coordinated attacks that could have saturated Patriot's traffic-handling capabilities.

(U) Illustrative of the levels of system leakage that may be achievable are the curves in figure C3 for single-tier and two-tier defense systems. The upper curve is for a system with a probability of sensor acquisition of 95% and a single-shot P_k of 85%. Leakage performance is 20% for a single interceptor shot and improves to 5% with three interceptor shots per warhead. Significantly lower leakage levels are achieved when a second tier with an independent sensor is added (lower curve).

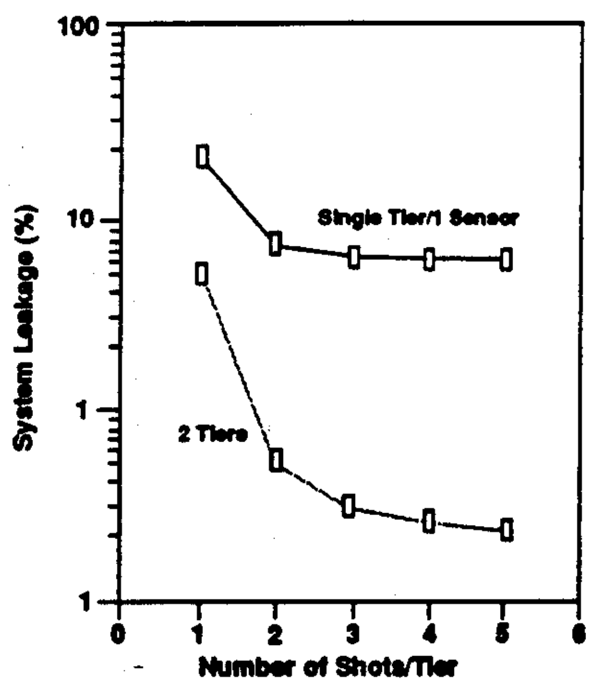

FIGURE C3.—Multiple Shots and Multiple Tiers Are Required To Achieve Near-leakproof Defense of Geopolitical Assets (U)

(U) Corresponding leakage levels improve to 4% for a single interceptor shot per tier and approach 0.2% for three interceptor shots per tier. Such a multiple-tier system with multiple shots and independent sensors is required to achieve near-leakproof defense of geopolitical assets.

E. INTERCEPT ISSUES

1. Altitude and Range (U)

(U) In general, the most desirable intercepts are as high above and as far away from the defended asset as possible. However, there are competing factors, particularly the need to control the conditions at intercept to achieve a high P_k.

(~~C~~) [redacted]

(U) More insight into the agent dispersal problem and into current research approaches may be gained by a review of work on one of the simplest warhead types—bulk-fill chemical tanks inside a conventional warhead shell. First, there are eight to ten well-characterized military chemical agents that have to be considered. From the viewpoint of the offense, these vary greatly in such important characteristics as toxicity, time to toxic effect, persistence in the target area, and difficulty to manufacture, store, handle, and dispense.

(U) Doses of some agents required to cause death or incapacity are indicated in table C3. A more complete list of agents is shown and table C4, and more CW effects are shown in table C5. CW experts find it usually most accurate to express the required quantities in terms of exposure time at a given density of agent in a given area. Therefore, the exposures are usually expressed in units of milligrams-per-minute per cubic meter ($mg \bullet min/m^3$). To approximately designate desirable keep-out zones, however, it is convenient to consider the amount of agent distributed over a given land area and to recognize that an area does of 10 mg per square meter can be assumed to be a safe level for most agents. (The safe dose for VX is lower.)

TABLE C3.—Some Chemical Agents And Their Properties (U)

AGENT	VOLATILITY† (mg/m³)	RESPIRATORY* LETHAL DOSE LCt_{50} (mg•m³/min)	RESPIRATORY* INCAP. DOSE ICt_{50} (mg•m³/min)	PERCUTANEOUS** LETHAL DOSE LCt_{50} (mg/m³/min)
Tabun (GA)	810	400	300	40,000
Sarin (GB)	22,000	180	75	15,000
Soman (GD)	3,900	180	75	10,000
VX	10	100	50	1,000
Mustard (HD)	920	1,500	200	10,000
Phosgene (CG)	4,000,000	3,200	1,800	n.a.
Hydrogen Cyanide	1,100,000	5,000	2,000	n.a.

Note: These estimates are for resting, unprotected adults; for highly active adults (e.g., soldiers in heavy combat) or children, the LCT_{50} and ICt_{50} could be three to four times lower.

* Median lethal and incapacitating damage for unprotected man breathing at the rate of 10 liters per minute.
** Median lethal dosage for a man in ordinary combat clothing.
† Mass of vapor per cubic meter at air of 25 °c. For comparison, the volatility of water at 25 °C is 23,000 mg/m³.

Source: FM3-9, *Military Chemistry and Chemical Compounds* (Washington, DC: Department of the Army, October 1975).

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(U) Many types of dispensers have been engineered to suit the different methods of delivering chemical agents (e.g., artillery, bombs, airborne sprayers). In general the dispensers attempt to break up bulk quantities of liquid agents into droplets of an optimum size so the cloud of droplets falls over as large an area as possible while maintaining sufficient concentration to be toxic. Adding inert materials to increase the viscosity and, thereby, encourage formation of larger droplets is desirable for most agents and most airborne dispensing mechanisms. Typically, mean droplet sizes of 100 to 2000 microns are optimum. A rough rule-of-thumb in the CW world that has important implications to the present problem is that droplets of 50 microns or less tend not to fall in a concentrated cloud or in a predictable fashion. Instead, under most atmospheric conditions, they bound around in low-level turbulence until they evaporate or until the cloud becomes so dilute that it is useless. Some recent research showing droplet size as a function of release altitude is shown in figure C4. Theoretical models predict the difference in behavior between 50-micron and 100-micron particles of the agent GF (figure C5).

TABLE C4.—Chemical And Biological Warfare Agents (U)

CHEMICAL	BIOLOGICAL
NERVE	BACTERIAL
GA (Tabun)	Anthrax
GB (Sarin)	Botulinum
GD (Soman)	Tularemia
GF	Plague
VX	Cholera
BLISTER	VIRAL
HD (Mustard)	Yellow Fever
H	Rift Valley Fever
HL	Junin Fever
L	Venezuelan Equine Encephalomyelitis
CX	
BLOOD	RICKETTSIAE
AC (Cyanogen Chloride)	Q Fever

Source: Holland and Pine, "SAIC Efforts in Chemical/Biological Defense for SDI-SEI." Unclassified internal SAIC briefing, July 1991.

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TABLE C5.—Some Fundamental CW Facts (U)

- A fair bit of agent is required: Typically, amount must exceed 10 mg/m^2
- Common figure of merit is: dosage = concentration x time
- Rule-of-thumb
  - ICT(50) = 1/2 LCT(50)
  - ICT(5) = 1/2 or 2/3 ICT(50)
  - Sure Safe = 1/100 ICT(5)

  Where:
  L = lethal
  I = incapacitating
- Example (for GB)

  LCT(50) = 75 mg•min/m^3
  ICT(50) = 35
  ICT(50) = 25

  Considerations must include mode of exposure: skin v. respiratory ingestion.

Source: R. McNally, "TMD Lethality Summary." SAIC unclassified internal briefing, 17 June 1991.

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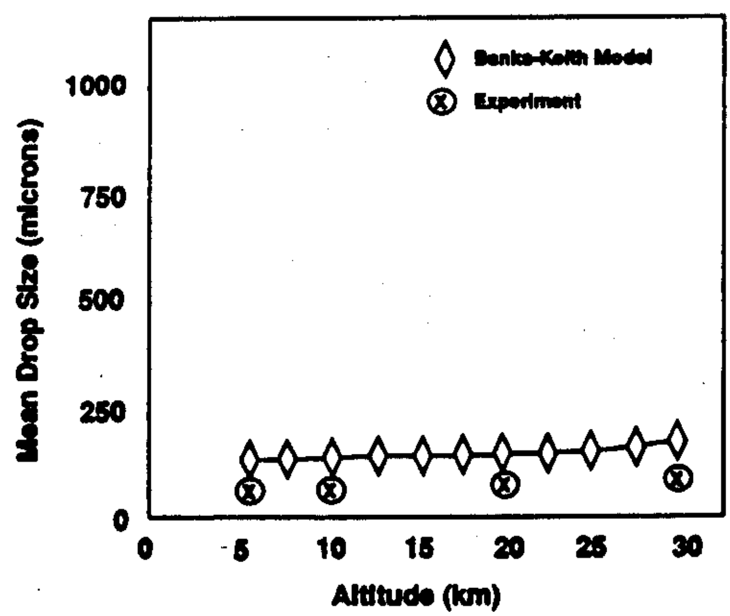

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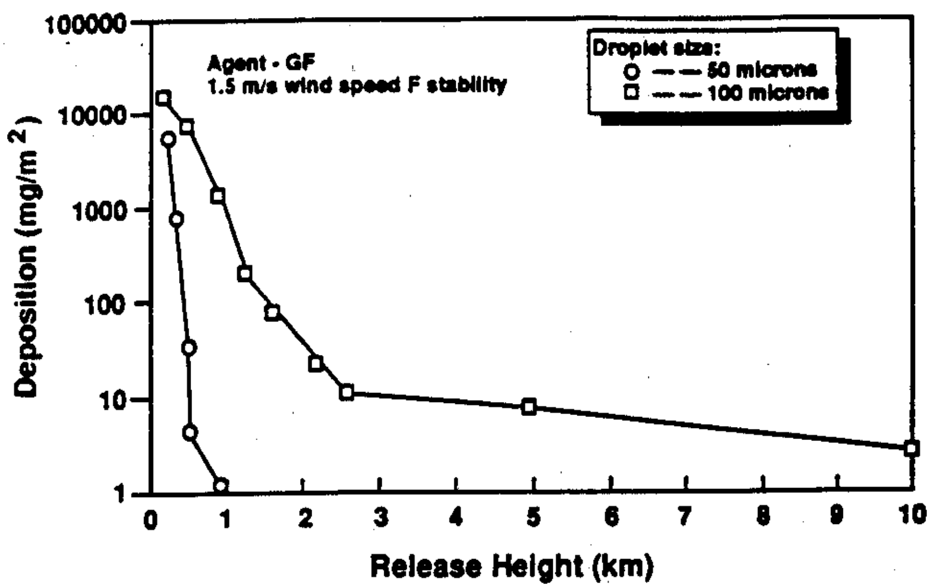
FIGURE C4.—Relationship of Reverse Ballistic Test Results to the Aerodynamic Breakup Models (U)



Source: R. McNally, "Tactical Ballistic Missile Intercept Issues for Chemical Warheads." Internal unclassified SAIC briefing, 25 March 1991

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FIGURE C5.—Peak Disposition Versus Release Height and Drop Size (U)

(U) A few words need to be said about biological agents. The problems of intercepting BW warheads are similar to, but not the same as, intercepting CW warheads. For example, many experts believe the BW weapon of choice for an Nth country would be anthrax spores. They are easy to make, have a long shelf-life, are resistant to temperature extremes and the exposure to oxygen and UV that might follow an intercept, and induce a usually fatal disease in 1 to 4 days. They require more agent than some other pathogens, but kilogram-for-kilogram, they are 100,000 times as effective as the common CW agents Sarin (GB).

(U) The anthrax spores, like most BW agents, would be dispensed as a powder rather than as a liquid. A significant problem for the offense is distributing the powder widely enough for it to be of optimum use. It seems clear that even an intermediate altitude intercept would help the aggressor achieve this goal. Intercept of a BW weapon—if one know that is what it is—should probably be carried out at as high an altitude as possible. Even with intercepts at some kilometers, however it is possible that spores could be carried along with the mixing interface and rained out on friendly or neutral territory many kilometers from the battlespace. Significant dilution will occur, however, negating much of the effectiveness of the spores.

(U) Modeling the dispersion of chemical or biological agents for various dispensing altitudes and wind conditions has been underway for some time. Some of the models are shown in table C6. One model is shown in more detail in table C7. Improvements in the phenomenology of the modeling are being made in the DNA lethality program where numerical techniques similar to those used in fallout prediction are being used.

TABLE C6.—Tactical Ballistic Missile Intercept Modeling for Chemical Warheads (U)

- Modeling Tools
  - chemical
    - NUSSE 3 ATM (no vapor damage effects)
    - NUSSE 4 (unvarying wind speed and direction above 200 m)
  - biological
    - VAMTECAP
    - PLUME (below the mixing layer only)
- Current models are completely missing key phenomenology
  - Vertical wind shears
  - boundary layer effects

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(U) The results of one of these modeling exercises is shown in figure C6, where the ground deposition of agent is predicted for various release altitudes. The persistence has also been estimated showing that in these cases, the agent is below acceptable levels in 15 minutes.

TABLE C7.—ATM NUSSE3 (U)

- CRDEC Code
- Describes the fraction of liquid reaching the ground and vapor concentration from a chemical agent cloud of droplets released at a given altitude
- Requires initial cloud and droplet size distribution and meteorological profile
- Computes droplet motion and evaporation as a function of time
- Output includes
  - droplet impaction start and stop times
  - percent of liquid agent reaching the ground and percent vapor concentration
  - deposition size and location
  - discrete X-Y grid points of agent concentration on ground

Source: K. Bradley, "Theater Missile Defense Lethality Program." Classified SDC and DNA briefing, 1991.

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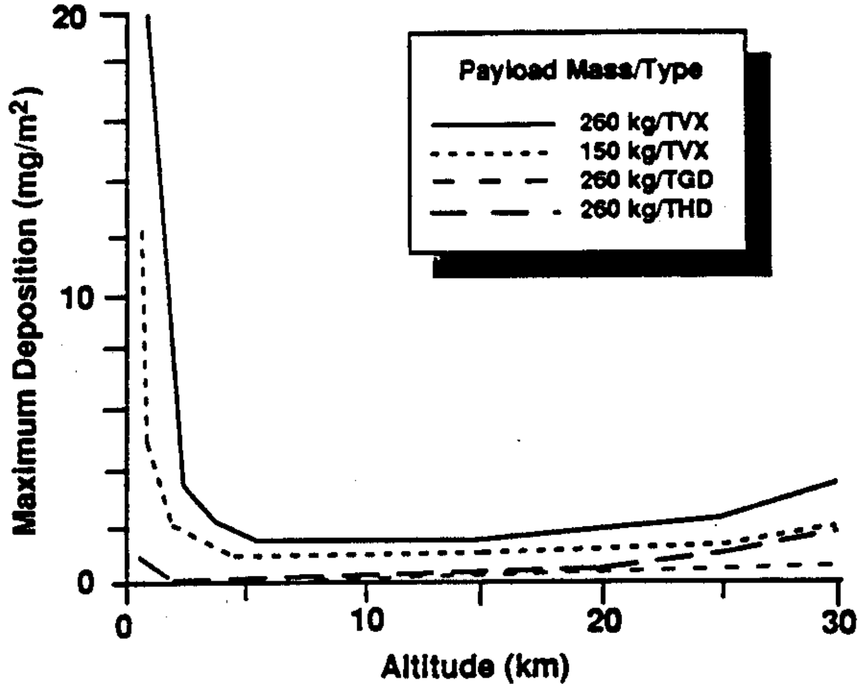
(U) Following are some observations and issues:

(U) • *For chemical munitions, what particle sizes are produced at higher altitudes and higher velocities?* This is a critical question, which SDC is addressing in a substantial experimental and theoretical program. The results to date are encouraging: Droplets appear to be "small" if formed above 2 km. If these results hold up, one would not expect much droplet penetration to the ground in the target area. An unresolved issue is whether the CW agent can be modified to form large droplets at high altitudes and still be efficiently dispersed at low altitudes.

(U) • *Where do the particles go?* The Army chemical laboratories have a set of codes, which are used for operational predictions but which do not cover the range of parameters needed in the TMD problem. The codes do not consider vertical motions of the atmosphere. In addition,they do not explicitly treat the "mixing interface"—the interface between the turbulent planetary boundary level and the more laminar flow above (typically 1000 to 2000 meters on a calm, sunny day; 200 meters at night; nonexistent in rain). There is a rule-of-thumb that small particles formed above the mixing interface do not readily fall through it, but the phenomena are not well-understood quantitatively. Thus, particle transport needs to be modeled.



Source: C. Martin, "Lethality Program Overview: A Hit Is Not Necessarily a Kill (U)." Classified DNA/SDC briefing to the Defense Science Board, August 1991.

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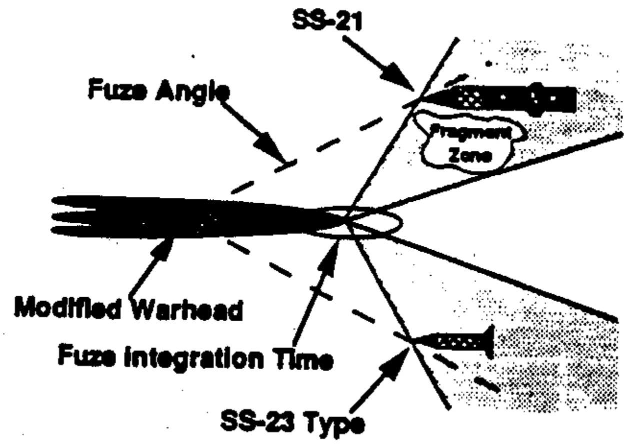
FIGURE C6.—Maximum Ground Disposition Predictions From a Catastrophic Release of a Modified Scud (Al Hussein) Chemical Payload (U)

2. Intercept Angles and Velocities (U)

(U) The P_k of an incoming missile is dependent on the orientation of intercept, the resulting impact angle, and the resulting relative velocity, among other parameters. For fragment warheads, the orientation affects both the probability of hitting the target and the P_k given a hit. The nature of the kill mechanism, such as the hit-to-kill (HTK) versus fragment kill, affects the choice of the most desirable intercept orientation. For fragment warheads, the fragment strike angles form the key parameter and depend upon the fragment velocity and distribution as well as the interceptor and target orientations and velocities. In a fragment kill, a relatively large fragment strike angle is needed to achieve fragment penetration. Velocities of 2 km/s or greater are needed to achieve a reasonable P_k. This P_k dependence for 200-gram fragments is shown in figure C7. For the current Patriot fragment warhead, P_k is very sensitive to the fragment strike angle.

FIGURE C7.—Warhead P_k Sensitivity to 200-Gram Fragment Strike Angle and Velocity (U)

(U) Available data indicate that the Patriot high fragment velocity, small fragment approach is only effective under particular conditions (high-density pattern on target) at which high fragment strike angles can be assured, e.g., slow (short-range) targets, low altitudes, near-zero intercept/target crossing angle encounters. Illustrative of a fragment warhead engagement is figure C8, which depicts the endgame geometry of the Patriot PAC-2 for a head-on, zero crossing angle engagement. Although the engagement is head-on,the fragments strike at a relatively high angle as a result of the fuzing and fragment blast pattern. As the intercept crossing angle is increased, the fragment strike angle is increased for half of the fragment pattern but decreased for the other half. Thus, the P_k decreases with increasing intercept crossing angle and is greatly affected by whether or not the warhead is fuzed at a receding or closing target. A number of phenomena, including the limited field-of-view distance of any on-board sensor and the fuzing mechanism, also play a role. In the case of the Patriot, the seeker limits engagements to maximum attack angles of approximately 30° from head-on, even for fuzing based on an active radar terminal homing sensor. The ability of the interceptor to maneuver in or out of the atmosphere also is a factor limiting terminal maneuvers and the resulting intercept angles.



Source: LTC S. Peth, USA. Briefing to the Joint Defense Science Board on GBR, 19 June 1991.

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FIGURE C8.—Patriot Head-on Warhead Kill Engagement (U)

3. Miss Distance (U)

(S) Similarly, minimizing the interceptor miss distance is vital for both HTK and fragment kill. Accomplishing this, of course, is greatly complicated if the incoming system has dispersed its warheads or is corkscrewing or otherwise breaking up in the atmosphere. Intercept altitudes [redacted] help minimize these problems. The Patriot system can be improved significantly [redacted] By one estimate,* the present miss distance [redacted] which could increase the number of fragments hitting the incoming missile by a factor of [redacted] There are still some differences in the community on the validity of this finding.

(U) Other factors that affect and impact the P_k include shaped charges, larger fragment size, and other innovative conventional warhead and fuzing schemes.

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*R. Brosch, "Ground Interceptor Engagement Performance and Lethality (U)." SAIC AIS Study Effort, 25 July 1991.

(U) It is clear that HTK intercept is even more sensitive to miss distance than is the fragment kill intercept. Hit enhancement, using an expandable, heavy metal web around the HTK vehicle, helps reduce miss distance. Such an enhancement device, however, uses the physics of fragment kill rather than HTK. The HEDI test (HTK with enhancement) worked will for HTK even in the presence of balloon PENAIDS at high altitudes. (In the TMD case, engagements are generally below 100 km; consequently the atmosphere acts to filter out balloon PENAIDS, making them less of an issue.) However, extensive and complete testing of the HTK approach needs to be conducted before a total commitment is made to this kill mechanism for new interceptors.

(U) In summary, our recommendations are as follows:

(U) • For fragment warheads, the trade-off to find both the flight and warhead parameters for achieving lethality needs to be carefully conducted for various terminal seeker and interceptor designs.

(U) • For HTK interceptors, a test program that can establish a high degree of confidence of intercept and lethality (under a variety of conditions) is needed as soon as possible and before completely committing to this kill mechanism. Aim-point selection on an extended warhead-booster target is an important issue.

II. TARGET KILL (U)

(U) Once an intercept is made, the issue of whether or not a kill occurred remains. there are two ways to look at this: 1) hard kill and 2) mission kill. Hard kill means that no damage has been done to allied assets, and mission kill means that no damage is done to the intended targets. Mission kill means that the incoming TBM has been diverted to miss the intended target. This is usually better than a miss, but there is probably no way to count on this kill mechanism in the TMD of population centers. Killing the incoming missile warhead is not the only problem because missile debris, including the incoming missile body in the case of a Scud, can impact a target area and cause a great deal of disruption—although less than if the warhead had detonated on target. Unfortunately, aerodynamic heating and burn-up cannot be counted on to damage the incoming TBM as much as it can be counted to damage intercontinental ballistic missiles. (However, the atmosphere does significantly slow the missile and debris so that its impact velocity is reduced.) Part of the solution to this problem is engaging the TBM at as high an altitude and as far from the defended area as possible. The two main kill mechanisms being assessed for TMD warheads are: 1) fragment warheads as on Patriot and 2) HTK warheads as in the case of ERINT and THAAD. In addition, numerous ideas for enhancing warhead lethality against biological and chemical weapons—including reactive agents—are being examined.

There is room and need for innovative warheads that might include shaped charges, focused fragments, or segmented rods.

A. HARD KILL (U)

(U) Table C8 reflect the state of our knowledge of interceptor hard kill lethality mechanisms for various types of threat warheads. In this table, directional warheads are included under CONVENTIONAL incoming warheads, and hard submunitions are the very robust runway cratering munitions. Many types of enhancers have been designed and tested. The last column in the table summarizes the enhancements that appear to be possible to add, in one form or another, to the kill mechanism. In sections 1 through 3, we discuss the status of our knowledge of these kill mechanisms.

TABLE C8.—Status of Lethality Knowledge for Hard Kill (U)

1. Fragment Kill (U)

(U) The effectiveness of fragment kill is determined by a variety of factors: the number of fragments hitting the incoming missile/warhead body, the energy and size of the fragments, where the fragments hit, fragment strike angle, fragment material fragment mass, and the shape and on the nature of the target warhead. Representative incoming warhead types and fragment kill lethality effectiveness are shown in table C8. The difficulty of accomplishing fragment kill varies drastically among threat warhead types. In the case of unitary HE or chemical warheads, the fragments can hit with enough mass and velocity (momentum) to achieve a hard kill. Kill methodologies for these warheads have been developed to estimate kill and are reasonably well understood. The most stressing conditions, again, arise with both HE and biological/chemical submunition warheads; it is believed that HTK warheads are required to kill a large percentage of the submunitions.

(S) [redacted]

- (S) [redacted]
- (S) [redacted]
- (S) [redacted]

(U) Ground tests can be developed to address part of the second and third categories but cannot include long-term effects. Flight tests also can address the third category but have difficulty in assessing the actual miss/encounter conditions and the submunition effects unless the test vehicles are recovered.

(U) Considering these problems, it may be desirable to obtain an early assessment using sled testing where the target will be at velocity and incorporate actual submunitions containing simulants. This would address many of the significant areas such as disabling or activation of the fuzing/dispensing mechanisms, rupturing and dispersal rate (including the aerophysical interaction), and enhancing interactions of the agent itself. Careful planning of diagnostics will be necessary to avoid picking up droplets before they have subdivided into their final size. It may be possible to obtain useful data on dispersal and droplet behavior by proper chemical doping of the simulated agent combined with laser stimulation and observation of the resulting cloud. This doping, illumination, and spectral observation approach could be taken further to provide indications of the temperatures, mixing, etc., experienced by the agents.

(U) As noted above, the high fragment velocity, small fragment approach used in the Patriot system is only effective against HE warheads under engagement conditions in which high fragment strike angles can be enforced. Analyses and simulations indicate that the multimode Patriot can enforce significantly smaller miss distances and, therefore, has the potential of achieving much larger numbers of fragment hits. Research by the Navy supports a defensive warhead design using a large number of small fragments as being effective against HE threat warheads. The efficacy of a large number of fragment hits at low strike angles against the relevant warhead types should be determined. There will be significant implications on Patriot growth options, achievable footprint, and the maximum range at which targets are engageable (enforceable strike angle does down with higher closing velocity) if high concentrations of small fragment impacts are effective at low strike angles. If not, other options, including a new, large-fragment warhead and various lethality enhancements need to be investigated. Parametric predictions of achievable P_k for large (200-gram) fragments were presented in figure C8. In this large fragment case, a relatively large strike angle is needed to achieve fragment penetration and velocities of 2 km/s or greater needed to achieve reasonable P_k.

(U) Even after optimization, it is doubtful that all chemical submunitions in an incoming warhead could be killed with fragments. (Agent leakage from perforated submunitions at intercept altitudes is another matter that requires investigation.) Thus, intercept as far from a target area as possible is important.

2. Hit-to-Kill Systems (U)

(U) A great deal of progress has been made over the last few years in HTK technology. Both computation and experimental test techniques have been used effectively to address the large array of technical problems associated with this issue. To date, the results of HTK flight experiments are extremely encouraging. Successful intercepts were achieved in the exoatmospheric HOE, ERIS, and ASAT tests as well as in the endoatmospheric FLAGE test. In all four tests, the intercepts were body-to-body impacts; the hit enhancers added to the interceptors to help ensure test success were not needed. Still, many uncertainties exist. The appeal of the HTK approach is the possibility of imparting large amounts of energy (~500 MJ) to a target system with the promise of totally destroying it. Some preliminary test results indicate that substantially less than 500 MJ may be adequate although it cannot be overemphasized that energy alone is not a sufficient figure of merit.

(U) In the case of HTK, the stressing threat is again the biological/chemical submunition. Figure C9 shows the test article. Table C9 shows the parameters for these calculations and some of the results. The energy imparted to the system varies by a factor of three and shows an important mass dependence for the P_k. This mass dependence for damage production needs to be understood by all users of the data. One-half scale test experiments imparting about 10 MJ to a submunition are in approximate agreement, with over half of the submunitions destroyed. This scales to about 100 MJ for a full-scale system. These kinds of comparisons of theory and experiment using gas guns and sleds as well as real flight tests are needed on a timely basis to validate HTK.

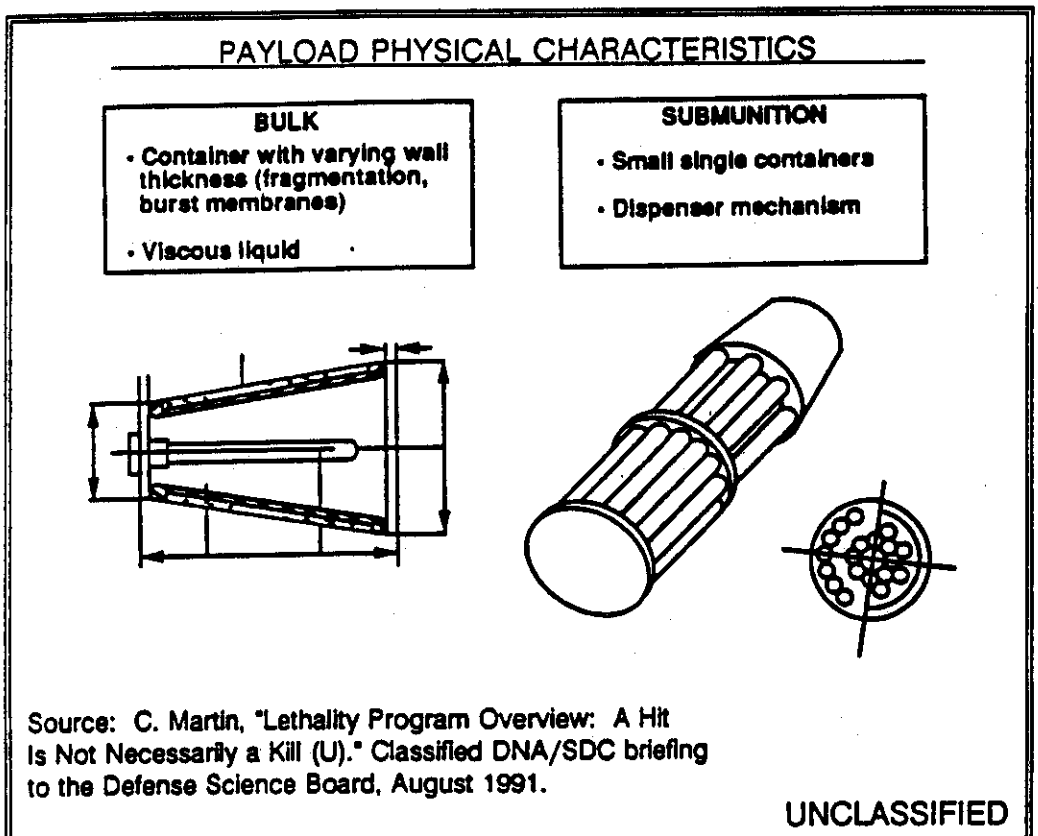

FIGURE C9.—Chemical Target Description for Experiment (U)

(U) There is a possibility that the uncertainty in aim-point selection against extended or closely spaced targets could be mitigated with several independently targeted submunitions in the TMD interceptor. This could, for example, have deliberately varying and possibly coordinated aim-point selection criteria. Before investigating this conceptual approach, it is important to quantify a minimum effective HTK mass against the various target warheads. To quantify interceptor performance and seeker imaging/aim-point selection requirements, the sensitivity to the degree of interceptor and target overlap must be established. If enhancer tests are not encouraging, more emphasis must be placed on guidance accuracy and interceptor design.

TABLE C9.—Summary of Hydrocode Results for Chemical Submunitions (U)

- Submunitions: Hydrocode calculations in support of HTK experiments
  - velocity: 1.7 to 3.0 km/s
  - scaled submunitions (1/2)
  - mass: 1 to 3 kg (scaled), L/D = 5
  - density = 2.0 g/cm^3 for HTK vehicle
- 3 kg, 3 km/s, 35° angle with C.L. = kills all submunitions
- 3 kg, 1.7 km/s, 35° angle with C.L. = kills approximately 2/3
- 2 kg, 3 km/s, 35° angle with C.L. = kills all, barely
- 1 kg, 3 km/s, 35° angle with C.L. = kills 1/3 to 1/2

Source: K. Bradley, "Theater Missile Defense Lethality Program." Classified SDC and DNA briefing, 1991.

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(U) The schedule for ERINT vehicle flight test program is shown in figure C10. Unfortunately, the submuntion test will not occur until 1993. The ERINT approach holds a great deal of promise because the energy available for kill is over 350 MJ. However, the development (schedule and design) of THAAD, using the HTK mechanism, could be impacted if something unexpected occurs in the ERINT test program. Another unknown with HTK vehicles is their ability to kill extended targets such as aircraft if the defensive system is to have both anti-air and antimissile capabilities.

(U) The Lightweight Exoatmospheric Agile Projectile (LEAP) Program uses more advanced HTK technology. In this program, hypervelocity projectiles will be developed. The two competing concepts are being researched by Boeing and Hughes. The critical research issues include miniaturization of the propulsion system, signal processing, seeker and avionics systems, and the integration of technologies to develop a complete projectile that meets the program's weight goal. In addition, General Electric is developing the D-2 hypervelocity projectile that is expected to be an all-weather, dual-mode, guided, lightweight, HTK projectile that can withstand high g forces of railgun launch. There are a number of complex technical issues to be resolved in the LEAP Program, including the seeker and maneuverability. Results that can be applied operationally are some time away.

	FY 91				FY 92				FY 93				FY 94			
	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
DPG Pre-flight Data Collection Resolution		Δ	—	Δ												
Certification ETS Bulk Target Flight					Δ											
Intercept Guided ERINT Test Flights (bulk)							Δ	Δ								
Certification ETS Submunition Target Flight										Δ						
Intercept Guided ERINT Test Flights (submunition)											Δ	Δ				

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FIGURE C10.—TMD Flight Test Schedule for ERINT Lethality Test

3. Lethality Enhancement (U)

(U) A number of interceptor warhead enhancements are being considered. It is too early to tell whether any of them hold promise. Simulation indicates that, within the atmosphere and against large extended targets, there is some question of minimum enforceable miss distance relative to the target's vulnerable area—even if the vulnerable area is known. However, when lethality enhancers are designed to supplement HTK, there is a high confidence of putting a small number of large fragments on the vulnerable area. A key question, then, is what the combined effects are of HTK and a small number of fragments against the relevant warheads. The region of interest is 2 to 3 fragments at 200 to 500 grams at low strike angle from the enhancer.

(U) An Enhanced Kinetic Energy (EKE) research program is underway on lethality enhancement against chemical weapon carriers. The interceptor payload would include chemicals that would destroy the CW agent, perhaps through heat produced in violently exothermic reactions. Because the closing velocity of the two sets of chemicals may be thousands of feet per second, it would be necessary to mix bulk quantities of fluids in a very short time to prevent unreacted amounts of agent from continuing on their way.

(U) Tests were performed in 1988 and 1989 that indicated that at impact of about 700 m/s, approximately 70% of the chemical simulant could be destroyed with projectiles filled with 18% EKE while only about 10 to 20% could be destroyed with inert projectiles. The projectile used in these tests was designed with a cavity that was filled with either EKE or an inert substance so that the mass was kept constant. The projectiles were then mounted in a sabot and fired from a light gas gun into a stationary container of the simulant. Testing at higher velocities was not done until late 1990 because the EKE-filled projectile was breaking up during launch. After considerable effort, a new projectile that could withstand the higher launch forces was developed, and further testing, up to 3 km/s, indicates that in static tests, both the EKE and inert projectiles destroy approximately the same amount of agent for impact velocities above 2 km/s. However, in these static tests, the mixing of the EKE oxidizer and chemical simulant was processing better than expected from a real engagement; these results, therefore, are optimistic. In addition, producing a projectile that can penetrate and deposit the oxidizer effectively in both soft bulk chemical targets and very hard submunition targets is very difficult. The presence of the chemical in the center of the projectile lowers the areal density of the projectile so much that penetration into a mass of submunitions is greatly reduced.

(U) Another approach in which a reactive agent is incorporated inside an explosive submuniton is under study and test. The agent is intended to mix with the high explosive of the incoming warhead and produce significantly more energy. Thus far, there are no conclusive results.

(U) Given these problems and the fact that most TBM engagements will exceed 2 km/s, the efficacy of using EKE warheads against TBMs is questionable. However, this type of warhead may have utility in attacking low, slow-flying cruise missiles and aircraft threats. Further testing and development for that application should be considered.

B. MISSION KILL (U)

(U) Mission kill has been defined to mean that the defense has caused the TBM to miss the intended military or population center target even though the TBM warhead may not have been destroyed. The debris for the interceptor-TBM encounter does, however, hit somewhere. Table C10 shows the status of our lethality knowledge. Hard information on bulk HE was obtained from Patriot's performance during Desert Storm.

TABLE C10.—Status of Lethality Knowledge for Mission Kill (U)

Definition: Warhead/submunitions do not impact on intended target

Caveats: Live warhead/submunitions detonate and structural fragments impact in large area target (e.g., cities)
Nuclear warheads salvage fuze above intended HOB
Nuclear debris/undestroyed biological and chemical agents fall out somewhere

INCOMING WARHEAD TYPES	INTERCEPTOR LETHALITY MECHANISM: FRAGMENTS	HIT-TO-KILL	ENHANCERS (RODS, EFPs, ETC.)
Conventional			
unitary	yes(P)	yes	yes
enhanced	yes(P)	yes	yes
submunitions	yes(P)	yes	yes
hard submunitions	yes(P)	yes	yes
Chemical			
unitary	yes(P)	yes	yes
submunitions	uncertain	likely	likely
Biological			
submunitions	very uncertain	very uncertain	very uncertain
Nuclear			
implosion	uncertain	uncertain	uncertain
hardened	uncertain	uncertain	uncertain

yes = job can be done with this lethality mechanism
(P) = status supported by Patriot capability/experience

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C. CONCLUSIONS AND RECOMMENDATIONS (U)

(U) Fragment lethality studies need to settle issues such as optimum size for a given fragment warhead. A fragment interceptor system may degrade more gracefully than an HTK. This needs to be investigated.

(U) The validation experiments and supporting calculations on the HTK approach should move rapidly, especially for chemical submunition targets. The lethality test program for HTK validation needs to be time-phased with the development programs for new systems such as THAAD. An early test of the probability of agent leakage from impacted submunitions would be valuable. Maneuvering targets and extended targets with especially vulnerable areas need consideration.

(U) An enhanced level-of-effort is needed on problems of lethality against biological weapons. While the BW work, to a large extent, can piggyback the chemical lethality program, BW involves some special considerations, particularly because small amounts of BW agents can be harmful. An area of emphasis should be atmospheric transport of agents for intercepts above 2 km.

(U) Lethality for EM gun interceptors and airplane-based boost-phase laser approaches need to be considered even though the current HTK technology programs address these issues in part.

(U) Is there hope for EKE interceptors? These are interceptor warheads carrying chemicals that will, it is hoped, burn up biological or chemical agents *in situ*.

(U) The SDIO should consider the impact if interceptors are not able to destroy entirely an incoming biological or chemical warhead. Kill—whether hard kill or mission kill—has been considered binary. This simplification may not be adequate; the problem needs to be thought through.

(U) Because it is often necessary to use multiple interceptors to increase P_k, emphasis needs to be placed on effective kill assessment as well as on effective mechanisms for target destruction and the interplay between the two.

(U) A variety of kill approaches are being studied; the studies are at varying degrees of maturity. Probably, our understanding of fragment kill is the most advanced, but it is not definite that this is the best approach. Thus, a mixed force of kill vehicles could be the safest approach, especially in light of the fact that TMD systems may have to defend against air-breathing threats as well.

(U) The SDIO/DNA should assist the JCS/CINCS in assessing expected collateral damage in TMD scenarios. This should be done through exercises when possible. Effective passive defense measures need to be refined based on experiences such as Desert Storm.

III. LETHALITY SUMMARY (U)

(U) Interceptor lethality against incoming warheads is a first-order issue for the Theater Missile Defense Program. Until quite recently, the SDIO interceptor lethality programs concentrated almost exclusively on lethality against long-range missiles carrying nuclear warheads. While these programs provide important background in both the science and the development of rational approaches to the lethality question, TMD lethality poses difficult new challenges. As a consequence, the Task Force concludes that a substantial lethality program focused on TMD is required and should be supported.

(U) One of the major problems posed in TMD is the need to develop, if possible, a single interceptor that will be lethal against HE, NBC, and incendiary warheads. The BW and CW agents could be contained in either bulk delivery tanks or submunitions. Some lethality mechanisms may be very effective against one type of warhead but not against another. HTK technology looks promising against a number of these warhead types. However, a weight and volume hedge is warranted for HTK to assure lethality. This would allow for future improvements, such as lethality enhancers, that may be needed.

(U) The general observations and conclusions of this study are provided in table C11. (Detailed recommendations are included at the end of each section.)

TABLE C11.—Lethality Summary (U)

OBSERVATIONS

- Lethality is a parameter the system developer can trade-off with other parameters.
- Lethality is a major technology uncertainty.
- A substantial, focused TMD lethality program is required.
- Analysis and confirming tests against some possible threat variations indicate that hit-to-kill or enhancers may be marginal for a hard kill.
- Hard kill, if achieved against all threats, is still accompanied by collateral debris and fallout.

RECOMMENDATIONS

- TMD Patriot and Standard Missile warhead upgrades should be undertaken.
- A comprehensive TMD lethality program should be supported.
- Early emphasis should be placed on chemical and biological submunition kills.
- A weight and volume hedge is warranted to achieve sure kill for HTK: This would allow for improvements to or combinations of HTK and enhancers
- Proliferated precision warning and civil defense measures should be supported to offset collateral environments.

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Definition: Hard Kill is the destruction of incoming warhead and submunition, detonation of on-board HE, destruction or dispersal of agents or nuclear materials in the upper atmosphere.

Caveat: High energy structural fragments will fall into a large area target, and nuclear debris or undestroyed biological and chemical agents will fall out somewhere. Nuclear warheads salvage fuze.

INCOMING WARHEAD TYPES	INTERCEPTOR LETHALITY MECHANISM FRAGMENTS	HIT-TO-KILL	ENHANCERS (RODS, EFPs, ETC.)
Conventional			
unitary	yes(P)	yes	yes
enhanced	yes(P)	yes	yes
submunitions	yes(P)	yes	yes
hard submunitions	uncertain	likely	likely
Chemical			
unitary	yes	yes	yes
submunitions	uncertain	likely	uncertain
Biological			
submunitions	uncertain	uncertain	uncertain
Nuclear			
implosion	yes	yes	yes
hardened	very uncertain	very uncertain	very uncertain

yes = job can be done with this lethality mechanism
(P) = status supported by Patriot capability/experience

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Appendix D (U)

COUNTERMEASURES–PENETRATION AIDS (U)

Seymour Zeiberg
Martin Marietta Company

~~SECRET~~

COUNTERMEASURES—PENETRATION AIDS (U)

A. INTRODUCTION (U)

(U) It is important to recognize that while Third World aggressors will be constrained in their ability to employ penetration aids (PENAIDS) against a theater missile defense (TMD), we will have uncertainty because of the unpredictability of their actions. This is in stark contrast the Soviet threat, which we have observed as it evolved over a long period of time. Third World capabilities can change quickly because they derive from technology and system transfers and direct sale of systems.

B. CONSTRAINTS ON THE AGGRESSORS (U)

(U) A number of factors constrain the aggressor's ability to employ countermeasures.

(~~S~~) The first constraint is the limit on the technology available to them. There is a large world market for aircraft PENAIDS but none apparently for devices appropriate for use with ballistic missiles. The United States has had, for decades, major programs focusing on offense-defense interactions [redacted] Descriptions of relevant PENAID technologies (for aircraft and missiles) appear in open literature and trade magazines but information on the highly system-specific methods to achieve design matching with missile systems and system integration matters does not. One can infer, therefore, that some generic PENAID technology and equipment could be available in an arms market but would require dedicated efforts to be incorporated into a particular system. [redacted]

(~~S~~) The second constraint on Third World aggressors is their inability to modify missiles and to package and deploy PENAIDS. [redacted] Seemingly mundane problems escalated to major issues that affected the design of the PENAIDS. Two examples follow:

(S) • [redacted]

(S) • [redacted]

(S) [redacted]

(S) [redacted]

(S) [redacted]

C. POSSIBLE PENETRATION AIDS (U)

(U) Uncertainty about what PENAIDS US TMD systems are likely to encounter are engendered by the same factors we believe limit potential aggressors. We do not know what level of technology the aggressor has access to; we do not necessarily know where the system was acquired; and we do not have the opportunity to observe system tests. This leads us to the situation of having to put ourselves in the potential aggressor's mind and to define approaches to ensure that our TMD system can cope with the potentially diverse, though not necessarily sophisticated, PENAID alternatives available to a technically clever but resource-limited aggressor.

(U) Table D1 shows examples of PENAID approaches deduced on the basis of how a Scud could be used and shows approaches that might be achievable with minimum modification or with major modification to the Scud. The table notes approaches observed during Desert Storm. (These were also observed during the Iran-Iraq War of the Cities and in Afghanistan.) Two PENAIDS come "free" with the Scud system: fragmentation of the unseparated missile tank and spiral maneuvering that results from the aerodynamic forces acting on the asymmetric, partially fragmented tank. In addition, high-rate attacks were used in the conflicts cited—up to 25 missiles per hour in the War of the Cities and up to 10 per hour (with as many as 7 in the air simultaneously) in Desert Storm. Even higher rates and quantities of missiles—and many missiles arriving essentially simultaneously—are likely to be one of the aggressor's options given a modicum of command and control capability.

TABLE D1.—Penetration Tactics and Techniques (U)

Scud	Scud (Minor Mods)	Scud (Major Mods) or Other
Fragmenting tank[†]	Tailored tank—frag radar and optical targets	Exotethers radar and optical*
Corkscrew maneuver (uncontrolled)[†]	Random jinking*	Exochaff and decoys (balloons)*
Large number[†], high rate[†], and simultaneous attacks	Jamming (main beam, on tank)*	Early reentry chaff and traffic decoys*
Frag screen —using tank frag screen* —using pressure HE WH bursts*	Leak residual fuel*	Programmed jinking (using tailored frag)*
	Seeded, ablative patches on RV and tank* optical signal perturber*	Retro tank, and place ahead of RV then frag, etc.
	Flare dispensing*	Reduce radar and optical signature "Stealth" levels
	Low and high reentry angle trajectories	

[†]observed in Desert Storm
*anti-hit-to-kill

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(U) Table 1 also notes PENAIDS that might induce a systemic degradation of nonnuclear kill approaches, which might impair hit-to-kill intercepts. The item "Frag screen" in the **Scud** column pertains to the self-screening produced by either fragmentation or precursor (high explosive) warhead bursts for an in-line series of attacking missiles. That is, the first missile (partially) screens the second one; the second (partially) screens the third, etc. This provides the n^{th} missile with an improved probability of penetrating the defense.

(U) Tailored fragmentation refers to the use of shaped charges to preferentially fragment the tank into large pieces that produce more credible radar and optical targets than does natural tank break-up in the atmosphere.

(U) The fact that the Scud does not separate the tank and warhead leads to an option to build in a main-beam jammer by attaching equipment to the tank (perhaps in a pod). Leaking of residual fuel results in reactions with high-altitude atmospheric constituents creating a diffuse, broadband optical tail that could distract optical trackers. Use of low- and high-angle trajectories, combined with high-rate attacks, could be a taxing strategy. While the Iraqi-modified Scud appears to be limited to only one trajectory (hard-wired guidance and control), modification should not be difficult. By reference, in the 1970s, the United States flew three Atlas missiles on 6-degree trajectories as part of reentry vehicle experiments in the ABRES Program.

(U) The items in the **Major Mods** category require separation of the warhead from the tank and moving the tank away so that it does not act as a beacon or acquisition aid to the defense. This category required extensive full-scale testing to prove-out various aspects of functionality.

(U) As mentioned in the text, the tactic of dispensing a multiplicity of submunitions early in the trajectory needs further study to ascertain whether it would fall into the **Minor Mods** or **Major Mods** category.

D. US ABILITY TO COUNTER PENETRATION AIDS (U)

(U) The US missile defense community has substantial experience and a high level of sophistication in both the design of PENAIDS and the design of corresponding defense counter-countermeasures. No other nation—including the Soviet Union—comes close to matching our experience in this area. Importantly, Third World countries are markedly inferior in theory, design, testing, and refinement of penetration devices and the techniques for countering them. Accordingly, the Task Force is confident that a TMD system can be designed to cope with the PENAIDS that an unsophisticated—but clever—aggressor could mount and, in effect, drive the aggressor to need levels of technology that are beyond its reach. To be able to cope with surprises, however, the TMD designs must retain flexibility in their operation (e.g., algorithms, modes) to accommodate new knowledge obtained by observation of potential threats in operation or via intelligence.

(U) The US TMD Program would benefit greatly from incorporation of a PENAID design and test program using approaches in the context of "Third World Resource-Limited Engineering." The results of such a program should be used in the defense counter- countermeasure efforts.

(U) Finally, our TMD Program would benefit from a "Red Team" styled along the lines of the SSBN Security Program. The SSBN Security Program sought technical and operations methods to undermine SSBN security and used the insights gained to counter those methods. The Program has been productive. An analog for the TMD efforts, coupled with the PENAIDS design and testing program recommended above, would be a viable approach to dealing with the threat of PENAIDS and the uncertainties that surround the threat.

Appendix E (U)

RELATED ISSUES (U)

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A. RELATION TO COUNTERFORCE (U)

(U) In its work, the Task Force frequently noted linkages between offensive action against ballistic missile threats and active defense against them. The very large effort expended to attack Scud missiles and missile launchers during Desert Storm suggests that one benefit from increasing the capability of ballistic missile defenses would be to free offensive air resources for other high-priority missions, especially during the early phase of operations, to establish air superiority. The other side of the coin, however, is the possibility that offensive air operations may be able to suppress ballistic missile rates-of-fire, easing the requirements on defenses to meet saturation attacks. A comparison of experience in Desert Storm with the earlier War of the Cities between Iran and Iraq is suggestive but far from conclusive in this regard. An understanding of the relationship would be helpful in planning theater missile defense (TMD). Finally, it is likely that space-based sensors for TMD would also prove to be of considerable value in targeting offensive action against mobile ballistic missile launchers, especially in a counter-battery mode. The Task Force supports the effort by the Brilliant Eyes Program to consider this interaction in its R&D efforts.

B. ALLIED ROLE IN TMD DEVELOPMENT AND DEPLOYMENT (U)

(U) To realize the interests in TMD it shares with its allies, the United States must consider how TMD deployment affects their strategic interests, their policies on arms control, and their role in the development of TMD systems. How the costs of TMD programs will be shared must also be a consideration. The Task Force notes that the Department of Defense has actively discussed the reorientation of the Strategic Defense Initiative Program to the Global Protection Against Limited Strikes concept with our principal allies; the Task Force believes equally strenuous efforts should be focused on informing them of our plans to meet the TMD objectives established by the Secretary of Defense and the Congress. Such discussions should embrace our R&D plans and the possible roles allies might play in implementing those plans. The initial exploration of arrangements for deploying such systems by US forces and for sales to allies also should be addressed in those discussions.

C. RELATIONSHIP OF TMD AND AIR DEFENSE (U)

(U) The Task Force did not address the relationship of TMD to theater air defense. This would be, however, an appropriate topic for a follow-on study.

(U) One can easily point to elements of synergism wherein a TMD system could contribute substantially to air defense. Patriot and Aegis can perform both roles, albeit with limitations in the case of advanced tactical ballistic missiles. An important question for follow-on work is whether an advanced TMD system, such as the THAAD/GBR, should be designed to handle both advanced air-breathing *and* advanced missile threats. There are substantial differences in what one wants in a THAAD interceptor to make hit-to-kill intercepts at 30-km altitude and in an air defense interceptor to engage a low observable cruise missile at 200-ft altitude.

(U) Of course, the THAAD/GBR combination could be very useful for intercepts of very fast (e.g., Mach 4) cruise missiles at high altitudes (in the 25-km regime). There is no clear or obvious answer to how much of the air-breathing threat should be assigned to an advanced TMD system or what synergy results from the deployment of air defense units in the area defended by a TMD system. Study is required.

DEPARTMENT OF DEFENSE
DIRECTORATE FOR FREEDOM OF INFORMATION AND SECURITY REVIEW
1155 DEFENSE PENTAGON
WASHINGTON, DC 20301-1155

28 JAN 1999

Ref: 91-F-2387

Mr. Peter Hayes
The Nautilus Institute
1831 Second Street
Berkeley, CA 94710-1902

Dear Mr. Hayes:

This is in response to your December 6, 1991 Freedom of Information Act (FOIA) request.

The enclosed documents are provided to you as responsive to items 4 and 5 of your request. No Department of Defense information responsive to items 1-3 of your request could be located. Ms. Cheryl P. Lynum, Chief, Management Oversight Division, the Ballistic Missile Defense Organization, and Dr. George W. Ullrich, Deputy Director, the Defense Special Weapons Agency (now the Defense Threat Reduction Agency), have determined that portions of one document must be denied pursuant to 5 USC § 552 (b)(1). The deleted information is currently and properly classified in accordance with Executive Order 12958, Section 1.5(a), concerning military plans, weapons systems or operations; or Section 1.5(g) which concerns vulnerabilities or capabilities of systems relating to the national security.

You have the right to appeal Ms. Lynum's and Dr. Ullrich's decision to withhold this information. Additionally, should you deem this partial no record response to be an adverse determination, you may appeal this finding by offering justification to support additional search effort. Any appeals must be received in this Directorate within 60 calendar days of this letter's date.

There are no chargeable costs for processing your FOIA request in this instance.

Sincerely,

A. H. Passarella
Director

Enclosures:
As stated