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A SUMMARY STUDY

OF

STRATEGIC OFFENSIVE AND DEFENSIVE FORCES

OF

THE U.S. AND USSR

Prepared for

The Director of Defense Research and Engineering

8 September 1964

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BASIC REFERENCE DOCUMENTS

Army study - Headquarters, Department of the Army study, "Damage Limiting Capabilities of Ballistic Missile Defenses and Terminal Bomber Defenses," dated 22 July 1964 (OPS PL WP 77045/76396)

Navy study - Navy Department, "Damage Limiting Study"

Part I - "Action against Missile Launching Submarines"

Part II - "Sea Basing U.S. Nuclear Offensive Forces"

dated 1 August 1964

Air Force study - Department of the Air Force, "Project Blue Dart" four volumes, dated 1 August 1964

OCD study - Office of Civil Defense study, "The Damage Limiting Potential of Civil Defense Programs," dated 1 August 1964

WSEG study - Weapons System Evaluation Group Report 79, "Analysis of General Nuclear War Postures for Strategic Offensive and Defensive Forces", two volumes, dated August 1964

ABBREVIATIONS

Below is a list of abbreviations used in this study and their meanings:

AADS-70 - Advanced Air Defense System - 1970, a surface-to-air missile system using NIKE - X - type technology

ABD - Area Bomber Defense (by interceptors)

AMSA - Advanced Manned Strategic Aircraft

ASW - Anti-Submarine Warfare

AWACS - Airborne Warning and Control System, a system for controlling interceptors

BAMBI - Space Based Boost-Phase Intercept

BMD - Ballistic Missile Defense, a terminal system for intercepting missile payload objects

BMS - Ballistic Missile Ship

B-n - A 197x version of POLARIS, a successor to B-3

CEP - Circular Error Probable

CV - Counter-value, an attack against non-military targets

CVS - Aircraft carrier designed for ASW use

C_{us} (C_{sov}) - The total dollar amount allocated by the U.S. (Soviet) to create population damage

DL - Damage Limiting

FFO - Full Fallout Shelter

HAWK/HERCULES - Combination of current high and low altitude surface-to-air missile defense units

HOB - Height of Burst

ICM - Improved Capability Minuteman

IMI - Improved Manned Interceptor

KP - Kilopounds, a thousand pounds of missile payload

L_{us} (L_{sov}). - The total dollar amount allocated by the U.S. (Soviet) to limit damage

MIRV - Multiple Independent Re-entry Vehicle, each R/V is independently aimed

MM, MM II, MM-G - Minuteman and versions of Minuteman

MSL - Missile

MVA - Manufacturing Value Added, a measure of industrial capacity which sums up the value that industry adds to the value of raw materials--stated as an annual rate

R/V - Re-entry Vehicle

SAMSA - Soviet Advanced Manned Strategic Aircraft

SAU - Surface (Ship) Attack Unit, employed in ASW

SBM - Small Ballistic Missile, a Navy designed missile using 197x technology

SLBM - Submarine Launched Ballistic Missile

SMSA - Standard Metropolitan Statistical Area, a unit used by U.S. Bureau of Census for the U.S.

SOF - Strategic Offensive Forces

SOSUS - Sound Surveillance System, an ocean survey system used in ASW

SRAM - Short Range Attack Missile, an air-to-surface missile of 197x

SSBN - Nuclear-propelled submarine armed with ballistic missiles

SSP_k - Single-Shot Probability of Kill

SSN - Nuclear Attack Submarines

TBD - Terminal Bomber Defense

TFX - A new interceptor (F-111)

WHDS - Warheads

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LIST OF FIGURES

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INTRODUCTION

A study, "Damage Limiting - A Rationale for the Allocation of Resources by the U.S. and the USSR" was prepared for the Director of Defense Research and Engineering and was released 21 January 1964.

One consequence of this study was a decision by the Secretary of Defense to amplify this type of study. The Deputy Secretary of Defense, in a memorandum dated 12 March 1964, requested that the Services conduct studies during the next six months that would focus attention on the objectives of "damage limiting" and "assured destruction." The goal was stated as "a much better understanding with regard to the following questions:

"a. For any proposed level of expenditures on 'damage limiting' forces, what is the 'optimum' allocation of the total among the various means that contribute to this function: civil defense; terminal ballistic missile defense and terminal bomber defense; area bomber defense; strategic offensive forces; and defense against Soviet missile-carrying submarines.

"b. What are the possibilities available with regard to limiting damage to the U.S. and our Allies? For example, what is the 'Percent Surviving' in the U.S. as a function of the total expenditures on damage limiting for various contingencies? From this one can make a judgement, taking into account present Soviet forces and possible changes in them, of the appropriate level of expenditures on damage limiting."

In response to the aforementioned memorandum, each of the Services and the Office of Civil Defense prepared a comprehensive study in depth of the contribution of each respective means of accomplishing the above defined objectives. The Deputy Secretary of Defense memorandum also requested the JCS to integrate and DDR&E to summarize the results of the component studies. The JCS assigned to WSEG the integration task (the report of which is hereinafter referred to as "the WSEG study"). WSEG was also assigned the task of providing standardized damage assessment runs.

This analysis is based on the component studies and employed the WSEG damage assessment data, adjusted for recent extrapolation of Soviet population data to 1970. Where results of the component studies could not be used directly, computations were made based on these studies to derive utility graphs in the desired form for trade-off with other major systems.

The data and results selected for use from the Service studies, as used in the DDR&E summary study, are at a fairly high level of aggregation. This selection does not constitute a critical review or an endorsement by DDR&E of all technical capabilities reported by the Services.

In summary then, this analysis examines the relative utility in a 197x time frame of six means of limiting damage to population and industry: (1) Civil Defense, (2) Ballistic Missile Defense, (3) Terminal Bomber Defense, (4) Strategic Offensive Forces, (5) Area Bomber Defense and (6) ASW Defense against the Submarine Launched Ballistic Missile.

METHOD OF ANALYSIS

The study is carried on in parametric fashion with emphasis throughout on optimum solutions--solutions characterized by least cost for a given outcome. The analysis consists of determining the proper allocation of dollar resources among the six means of damage limiting, each of which acts in a different way to negate the effects of enemy counter-value attacks. In making the allocations, the common denominator of comparison was the marginal cost to offset or negate the effects of an additional, reliable kilo-pound of missile payload. The use of this common denominator presumes that the payload is utilized to produce maximum fatalities, taking into account the character of the target and the nature of the defenses. In this connection bomber payload was expressed as equivalent missile payload on the basis of equal damage potential against urban-industrial targets.

For both missiles and bombers it was necessary to take account of the payload used to accommodate various penetration aids such as re-entry decoys, multiple warheads, and air-to-surface missiles. The term "virtual attrition" will be used to describe such reductions in "lethal" payload. A more complicated form of virtual attrition is also considered in connection with varying the size of individual ICBMs to maximize, at constant budget, the payload surviving a counterforce attack.

In a certain sense, the analysis is an extension of the DDR&E report of 21 January 1964. The qualitative results of the former study were used when appropriate. Slightly different costing ground rules, refinements of previously studied systems and the later time frame of the present study have had a slight change on some of the quantitative results. The addition of ASW, Area Bomber Defense and various specific component subsystems have produced major quantitative changes in some other cases.

FOCUS OF STUDY

The single guideline of the DDR&E study group has been one of providing illumination of the "Damage Limiting" and "Assured Destruction" problems, de-emphasizing specific weapon systems to the maximum extent possible. The group has concentrated on the questions finally to be answered: If the Soviets spend x dollars to create damage on the U.S., and the U.S. spends y dollars to limit damage, what is the percentage U.S. population and industry surviving? What are the results of the mirror image problem? (Note: Soviet "damage limiting" is the same problem as U.S. "assured destruction.") What scale-independent factors, if any, exist which will simplify the understanding of the objectives "Damage Limiting" and "Assured Destruction."

This study focuses on an existence theorem for damage limiting--can the U.S. maintain a damage limiting posture (a given level of surviving population) in the face of determined efforts of the Soviets to overcome that posture. This can be expressed in terms of exchange rates--the cost for the U.S. to maintain a given "% Surviving" per dollar of Soviet expenditure to overcome it.

COSTING

Specific costing ground rules were provided to the component study groups by OASD (Comptroller). All costs (except missile costs) through FY 65 were considered "sunk." All missile procurement costs were to be included because, in the time period of the study, 197x, present missiles would, for the most part, have passed their useful operational life. Two methods of costing were carried forward: (1) Present Value--i.e., total RDT&E plus initial investment costs (subject to "sunk" costs above) plus 5 years operating costs. This is equivalent to total initial costs, plus 10 years of annual operating costs discounted at 15% per year; (2) First 5-year fraction of long-lived, high-cost initial investments amortized using the "sum-of-years" method plus other non-amortized initial investment costs (e.g., RDT&E and spares) plus 5-year operating costs (not discounted).

[redacted]

All costs displayed in this study, unless otherwise noted, are "Present Value," i.e., (1) above. In computing marginal costs per Soviet units destroyed for the purpose of trade-off with competing means of damage limiting, (2) above was used to normalize over different lifetime systems.

In some cases component study costs had to be adjusted by OASD (Comptroller) to conform to the above rules. The OASD (Comptroller) also provided costs of Soviet weapon systems on a comparable basis--that is, with U.S. dollars from U.S. manufacturers.

CIVIL DEFENSE FOR U.S.

The analysis begins with a re-examination of the utility of Civil Defense. The results of the previous DDR&E study regarding the high relative utility of a full fallout shelter (FFO) were confirmed. Refined cost data indicates that 240 million spaces can be constructed for $5.2 billion. 1/ This figure was around $5.8 billion in the previous study. An FFO posture for the U.S. was purchased first and used as the base case for subsequent analysis.

1/ The $5.2 billion is total GNP cost, $2.9 billion of which would be federal government expenditures, with the remaining $2.3 billion to be provided by state and local governments and private individuals.

[redacted]

The previous study demonstrated that the utility of blast shelters (occupied by 90% of the population) and Ballistic Missile Defense (BMD) were about equal in saving population. Because BMD also saved industrial worth -- measured as Manufacturing Value Added (MVA) -- it was selected over blast shelters. The situation is essentially the same in the present study. Blast Shelters (with a 90% occupancy) trade-off evenly with active defense at attacks of about 8000 MT or higher (in addition to a 2500 MT military attack) while active defense has more value at lower attack levels. Active defense was selected over blast shelters and was used in the subsequent computations for the following reasons: (1) higher likelihood of lower attack, (2) uncertainties regarding the achievement of an occupancy of 90% from blast shelters, (3) uncertainties regarding the ability of people to emerge from blast shelters in the post attack period and (4) the added utility of BMD in preventing nuclear detonations over the U.S.

BALLISTIC MISSILE DEFENSE AND TERMINAL BOMBER DEFENSE FOR U.S.

In the previous study, BMD was interlocked with Terminal Bomber Defense (TBD) by designing TBD deployment so that the Soviets would always find it their best option to use bombers against undefended targets, independent of area penetration probability of bombers. It was observed that the cost of a TBD system, interlocked with BMD, was a small (5% - 10%) percentage of the BMD expenditure.

Throughout the study, unless otherwise stated, urban-industrial damage for both the U.S. and the USSR includes collateral effects from a nominal attack of about 2500 megatons on military targets. These military attacks were used to take into account the possible presence of collateral fatalities. In the course of examining damage limiting on both sides the high relative utility of a very good fallout shelter program for each country was determined almost from the beginning of the analysis. Deployment of these shelters reduced the collateral fatalities to a fairly small part of the total population. In the event of sizeable city attacks the effect of the presence of collateral fatalities on overall outcomes is reduced. A sizeable fraction of the people that would be killed by the military attack are killed by the city attack if only a counter-city attack occurred. Once each side has fallout shelter programs, the collateral damage from the military attack is thus a second order effect. It is included in the calculations -- but is not necessarily provided (or costed) in the campaigns. Reprogramming capability for known weapon failures (reliability) is assumed for both sides. Blast is the most prominent means of inflicting damage, especially, as will be later explained, since a full fallout shelter program is chosen almost from the beginning.

In this study a HAWK/HERCULES deployment at a total of 213 cities was initially made in order to (1) prevent serial bombing by Soviet bombers and (2) impose a virtual payload attrition on incoming bombers by forcing them to use smaller "lethal" payloads deployed in air-to-surface missiles compared with bombs.

As cities are defended by BMD, more sophisticated TBD (AADS-70), interlocked as in the previous study, replaces the HAWK/HERCULES batteries. Thus at every level of BMD, AADS-70 is deployed in the NIKE - X defended cities and HAWK/HERCULES elsewhere. More refined costing of both BMD and TBD in the Army study shows that the cost of a balanced and interlocked terminal defense is now about 1.2 times that of BMD alone.

COMBINED BOMBER DEFENSE FOR U.S.

In order to obtain some estimate of the trade-off between TBD and ABD, Area Bomber Defense (ABD) was examined for a pure bomber attack in relation to a light deployment of HAWK/HERCULES to prevent serial bombing and then in relation to increasing numbers of AADS-70 defended cities--with HAWK/HERCULES elsewhere. By comparing the marginal costs per bomber payload destroyed, an optimum mix of ABD and TBD was derived for a pure bomber attack. It was determined that ABD was closely competitive with TBD. Although 50% variations in cost (of either TBD or ABD) or bomber payload are sufficient to drastically alter the optimum percentage allocations between TBD and ABD, the total combined cost--at optimum allocation for a given outcome--varies less than 20%.

The insensitivity of combined ABD/TBD costs to the exact allocation between ABD and TBD allows the TBD allocation to be chosen on the basis of placing AADS-70 at BMD defended cities and HAWK/HERCULES elsewhere. This interlocked TBD/BMD terminal defense was used throughout the calculations, but one is reminded that the combined cost of TBD/ABD would be quite similar had a more complicated allocation procedure been used.

For the case of Soviet second strike, the trade-off of U.S. ABD versus Strategic Offensive Forces (SOF) was also analyzed against the Soviet bomber threat. The optimum allocation was determined to be one U.S. reliable missile targeted against each Soviet bomber base. The question of SOF utility against Soviet bombers is thereby reduced to the matter of probability of kill of a reliable U.S. missile and occupancy.

AREA BOMBER DEFENSE FOR U.S.

The Air Force study compared the TFX (F-111) interceptor and the Improved Manned Interceptor (IMI) both with the Airborne Warning and Control System (AWACS). On the basis of equal U.S. cost both interceptors appear to perform about as well against the subsonic bombers. Although both interceptors do less well against the Soviet Advanced Manned Strategic Aircraft (SAMSA), the IMI does better than TFX. For this reason, and in order to focus on 197x technology, it was decided to emphasize IMI vs. SAMSA in the study of Area Bomber Defense. The IMI/SAMSA results can be readily translated into equivalent subsonic bomber attacks.

STRATEGIC OFFENSIVE FORCES FOR U.S.

A general analysis was made of the optimum deployment of the Soviet missile force against the threat of n reliable U.S. SOF missiles of a given single-shot probability of kill against a Soviet missile in a silo. The general answer was derived to the question: "Given a U.S. threat and a constant Soviet budget, how many ICBMs of what payload should the Soviets deploy in order to achieve the maximum payload surviving a U.S. attack?" The general result therefore yields the best that the Soviets can do at a given Soviet ICBM budget. In a sense this maximum is not always attainable because of uncertainties in estimates of the U.S. threat, n, and missile payload repackaging problems. Excursions were made showing the effects of the Soviets packaging the same payload per missile without regard to the threat.

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The utility of U.S. SOF is computed (unless otherwise noted) on the basis of the optimum Soviet deployment. This utility is measured in terms of the marginal cost per kilo-pound of Soviet ICBMs destroyed.

The existence of U.S. SOF provides a "virtual" attrition of Soviet KP even in Soviet first strike counter-value where U.S. SOF does not have an opportunity to operate on Soviet KP prior to its launch against U.S. cities. Without the threat of U.S. SOF the Soviets could deploy very large missiles. With larger missiles, they could deploy more payload for a given budget. Figure 10 elaborates on this aspect of "virtual" attrition.

U.S. ASW DEFENSE AGAINST THE SOVIET SLBM

The examination of the utility of Anti-Submarine Warfare (ASW) forces has focused on a steady-state, Soviet POLARIS-type operation. A nominal Soviet SSBN was used, having a [redacted] still class SECRET noise level, with 1500 n.m. missiles, 12 missiles per boat (18 KP/boat). Excursions to other cases were also made.

Types of ASW forces were sub-optimized by the Navy study group against the total Soviet Nuclear-powered Ballistic Missile Submarine (SSBN) threat. These types of forces included:

[redacted]

[redacted]

(1) Surface Attack Units (SAU) for trailing plus SOSUS/CVS "contact and localization" forces operating on those Soviet SSBNs on station upon receipt of the order to destroy Soviet SSBNs; (2) Carrier (CVS) forces operating on those Soviet SSBNs at sea that attempt to transit to the launch area; (3) SOF and forward area submarine (SSN) barriers that operate on those Soviet SSBNs in or near port that attempt to transit to open sea. The SSN forces were sub-optimized between barrier and trailing operations.

The sub-optimized ASW utility curves were used in this analysis.

FINAL TRADE-OFFS

The marginal costs to negate an equivalent missile kilo-pound (considering all losses, such as loss to penetration aids) by each of (1) ASW, (2) SOF, (3) ABD and (4) BMD/TBD/FFO were computed. For a given Soviet threat, at a fixed U.S. marginal cost, dollar allocations were made to each of the four above-named categories of forces and the percent U.S. population surviving was computed at this marginal cost. At this point, an additional dollar spent on any one of the types of forces brings the same return. These allocations thus constitute a balanced and optimum defense. It is to be noted that the marginal costs vary for different percent U.S. population surviving. The

[redacted]

final output yields graphs of: Percent U.S. Population Surviving, for the given Soviet threat, as a function of cost to the U.S., spent optimally, on CD/BMD/SOF/TBD/ABD/ASW to limit damage.

U.S. ASSURED DESTRUCTION

The U.S. "assured destruction" objective is equivalent to the Soviet "damage limiting" problem. The Soviet damage limiting possibilities are analyzed in the same manner, to the maximum extent possible, as that of the U.S. In keeping with the notion of "assured destruction," the analysis is focused on destruction of major Soviet cities as well as simply maximizing Soviet fatalities.

The WSEG damage assessment runs for 1.0 MT weapons on the Soviet Union were based on 1959 tract data and were carried out up to 900 weapons on 306 cities of population greater than 50,000. Tract data for later years are not available. However DIA shows a definite shift from about 46% (of the total) urban in 1959 to an estimated 56% urban (cities of 2000 and above) in 1970. At the same time the Soviet population grows from about 209 M in 1959 to an estimated 244 M in 1970.

The WSEG damage assessment runs were adjusted to take account for the rural-urban shift and, simultaneously, extended to larger numbers of 1 MT weapons (targeted at slightly more than one weapon per town of less than 50,000) in order to examine the full range of damage to Soviet urban populations.

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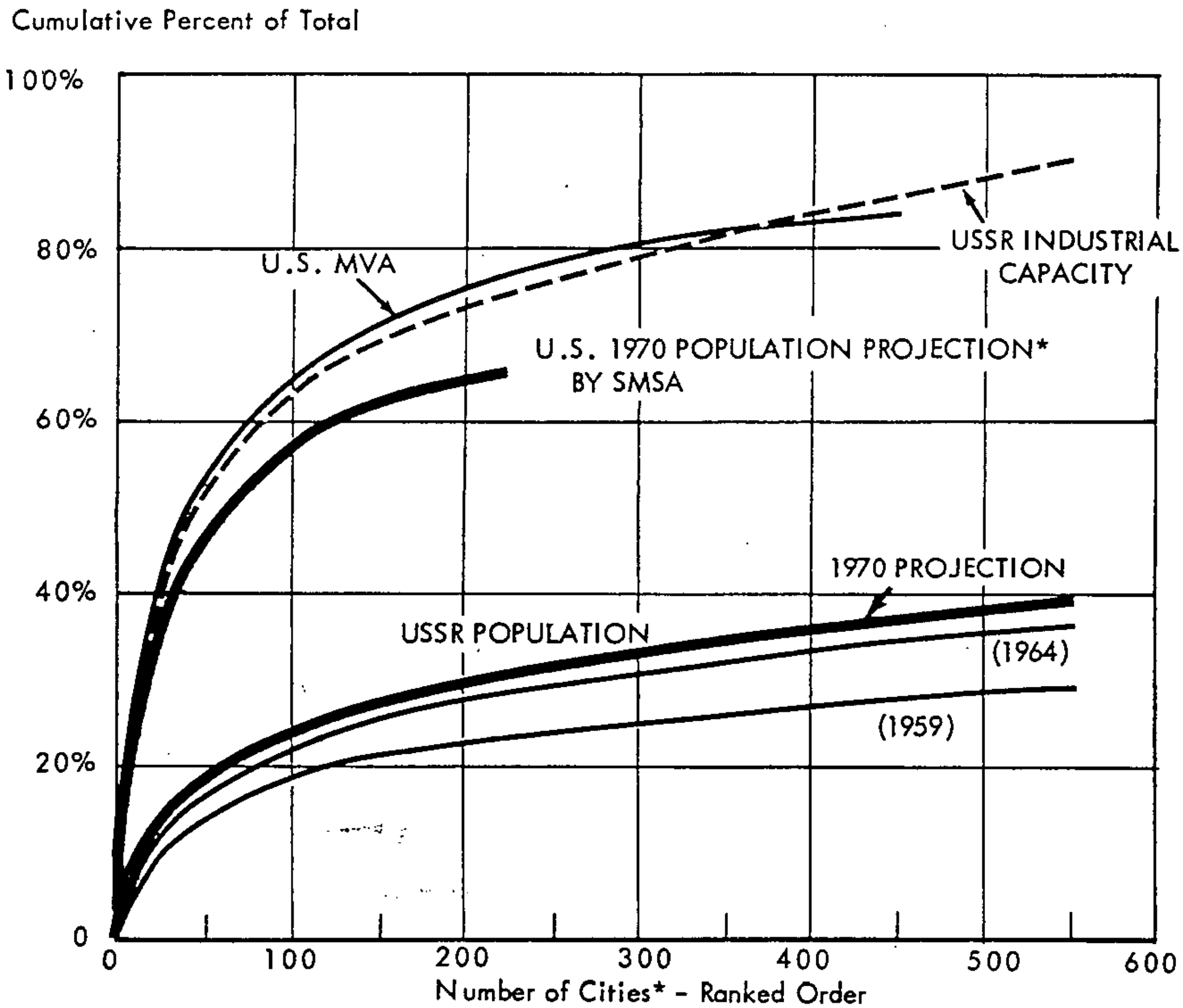
Figure 1

% U.S. MVA, USSR Industrial Capacity and
% Soviet Population vs Number of Cities and
% U.S. Population vs Number of SMSA



* NOTE: U.S. 1970 Population Plotted vs Standard Metropolitan Statistical areas
(212 Areas included 255 Cities in 1960 Census)

[redacted]

Figure 1

% U.S. MVA, USSR INDUSTRIAL CAPACITY AND % USSR POPULATION vs. NUMBER OF CITIES AND % U.S. POPULATION vs. NUMBER OF SMSAs

Purpose

1. To compare the distributions of value used in this study for the U.S. and USSR.

Basis for Computation

2. U.S. data uses "Standard Metropolitan Statistical Areas" (SMSA). These areas generally include one city, but may include as many as two or three cities located geographically close such as Allentown, Bethlehem, and Easton, Pennsylvania; or Duluth, Minnesota and Superior, Wisconsin. The Bureau of Census Statistical Abstract of the U.S., 1963, lists 212 SMSAs which include 255 cities.

3. SMSAs are used by Civil Defense in its blast shelter computations, but are called "cities" in the Civil Defense report. The 1970 U.S. population projection is that given by the OCD study. There is a 2% (of the total) increase in population living in these SMSAs from 1960 to 1970. Basis for percentages are:

	1960	Forecast 1970
212 SMSAs	112 M	138 M
Total Population	179 M	210 M
SMSAs 1-23	--	37% of Total
SMSAs 1-47	--	45% of Total
SMSAs 1-100	--	57% of Total
SMSAs 1-212	--	66% of Total

4. The 1959 USSR population curve was developed from the 1959 Census. The 1964 curve is based on the DIA "Annual Review of Demographic Composition, USSR" PC 460/1-1-64 dated 1 January 1964. The 1970 USSR projection is based on the same report, updated by factors provided by the authors of the aforementioned report.

5. The U.S. MVA (Manufacturing Value Added) curve is based on 1958 U.S. Census of Manufacturers Report. USSR Industrial Capacity curve is a 1960 estimate based primarily on gross industrial product.

6. It should be noted that only in Moscow and Leningrad does the urban population cover more than 100 square miles. In the U.S. 62 of the major urban areas cover in excess of 100 square miles. This compactness of Soviet cities results in population densities 2 - 3 times those in principal U.S. urban areas.

7. The basic USSR population data are:

(in Millions)

	Urban	Rural	Total	Urban* as % of Total
1959	100.0	108.8	208.8	47.9
1964	118.4	104.7	223.1	52.3
1970	138.2	106.0	244.2	56.6

* Urban population is defined as centers containing about 2000 or more people (approximately 6000 centers in the USSR).

Basic Points

8. In 1970, more than 50% of the U.S. population will live in 53 SMSAs; in the USSR even 500 cities will contain less than 40% of the total population.

9. The difference between the U.S. and Soviet population distribution is evident from the graph. This difference presents a large asymmetry in the weapons required for "assured destruction" with regard to total population.

10. The distribution of Soviet industrial value is very close to that of the U.S. However the industrial value in the USSR is locally more concentrated -- in cities of smaller areas (note 6 above) -- and thus takes fewer weapons to destroy a given percentage.

11. The asymmetries in population distribution and industrial capacity concentration will produce asymmetries in the damage limiting and assured destruction results for both sides.

12. The marked Soviet rural-urban shift is an important consideration in future U.S. strategic decisions regarding assured destruction.

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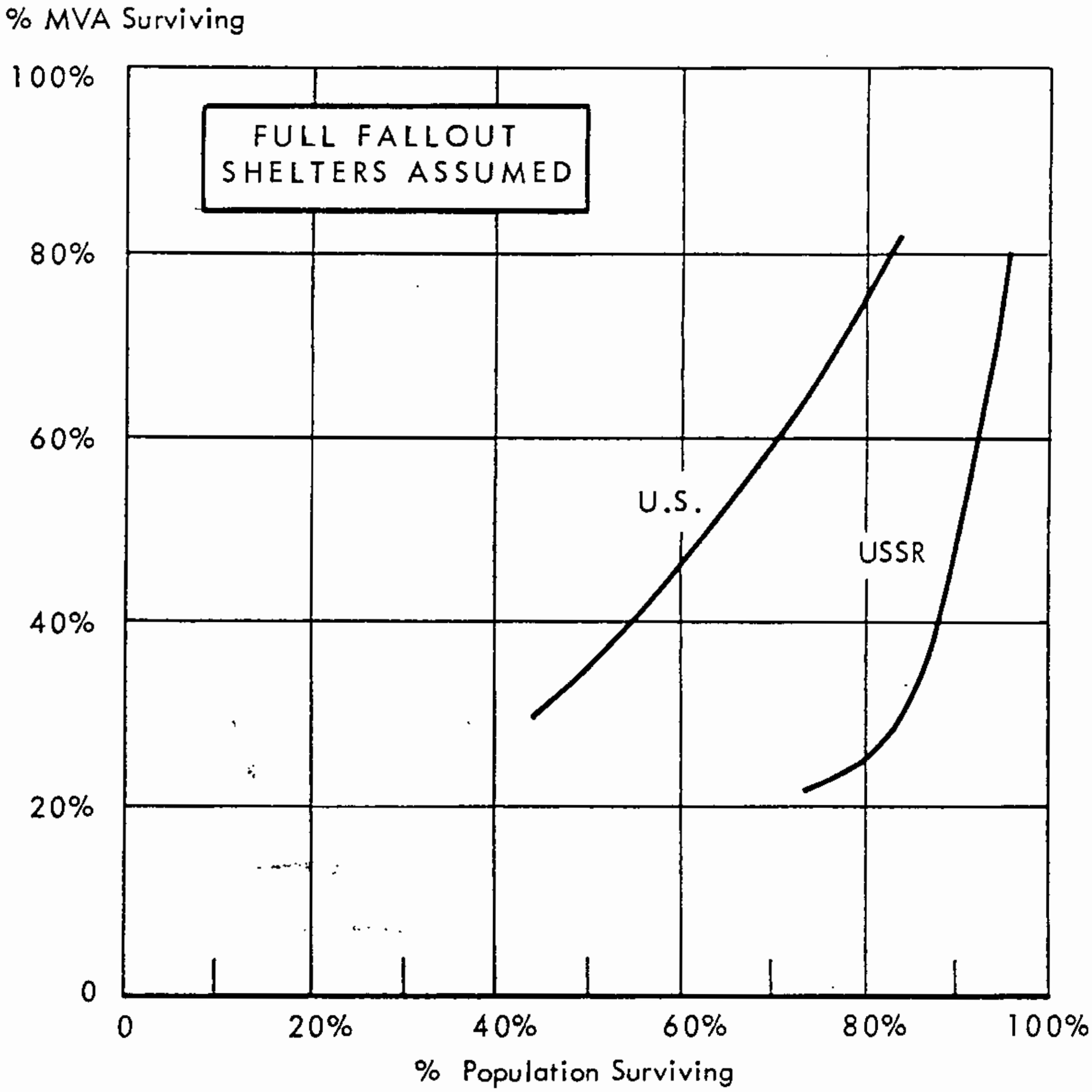
Figure 2

% MVA Surviving
vs
% Population Surviving for the U. S. and the USSR



[redacted]

Figure 2

% MVA SURVIVING vs % POPULATION SURVIVING

Purpose

1. This graph shows, for both the U.S. and the USSR, the relationship between percent MVA and percent population surviving.

Basis for Computation

2. The previous DDR&E study showed the high correlation between percent population and MVA surviving, given a full fallout shelter, over a wide range of attack sizes and defenses.

3. When the percent U.S. MVA surviving from the WSEG damage runs is plotted against percent population surviving, the results fall within 2 - 3% of the curve given in the previous DDR&E study. Thus the previous result is confirmed.

4. This graph shows the relationship between percent MVA and percent population surviving for the U.S. and the USSR. In each case a full fallout shelter is assumed. Attacks are optimized for blast fatalities.

Basic Points

5. The relative vulnerability of the USSR MVA and relative invulnerability of the total Soviet population is quite evident from these curves. In the case of the U.S. the vulnerabilities are more closely related.

6. The analysis will consider population surviving as a measure; these correlations can be used to relate the percent surviving

population to percent surviving industrial capacity. NOTE: The non-linearity of the USSR curve makes the relation sensitive to which people are surviving. (Going from 95% to 90% population surviving, the industrial capacity surviving goes from 80% to 50%. But a 5% decrease in population surviving from 80% means only about 5% decrease in industrial capacity).

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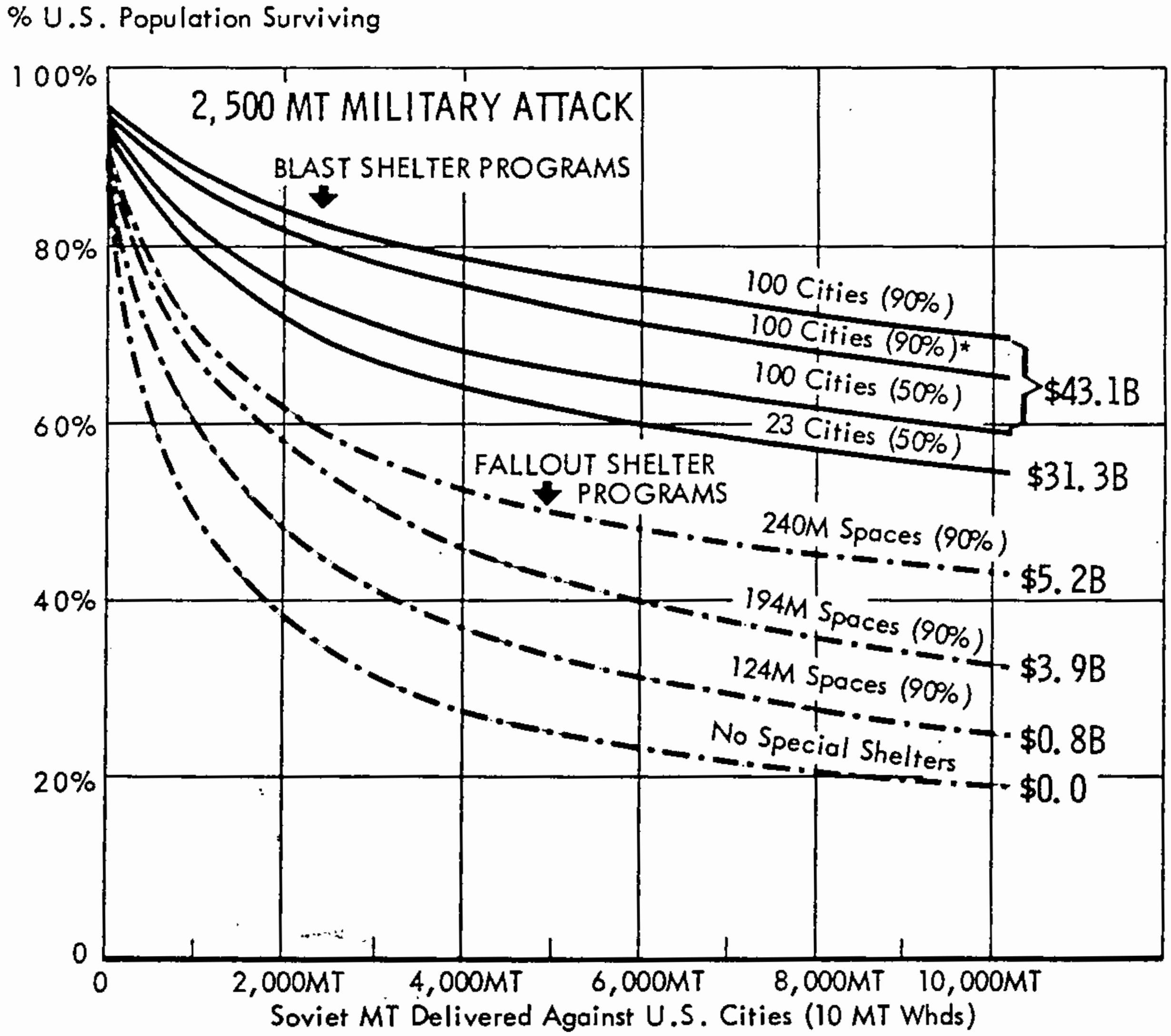
Figure 3

% U.S. Population Surviving
vs
Number of Soviet Megatons Delivered against U.S. Cities for Various Civil Defense Shelter Postures



* Attacks for this curve optimized vs 100 PSI. All other curves vs 10 PSI.
Note: % Occupancy of indicated shelters in parenthesis.

[redacted]

Figure 3

% U.S. POPULATION SURVIVING vs. MT DELIVERED AGAINST U.S. CITIES

FOR VARIOUS CONSTANT BUDGET CIVIL DEFENSE POSTURES

Purpose

1. This graph displays the utility of various Civil Defense (CD) postures.

Basis for Computation

2. All curves were derived from the Office of Civil Defense (OCD) study. The case of "No Special Shelters" (OCD Case "OA") assumes that U.S. population is warned.

3. All weapons on U.S. cities are 10 MT each -- surface burst. If the attack is made with 1 MT weapons rather than 10 MT weapons, the percent U.S. population surviving is about 5% (of total population) less at the same total delivered megatonnage. This is with full fallout protection. The weight of the attack delivered on U.S. cities is in addition to 2500 MT delivered on U.S. military targets.

4. Attacks on cities are optimized for 10 psi overpressure, even when the U.S. has blast shelters. If the attacks were optimized against 100 psi, the percent U.S. population surviving is about 5% less at 10,000 MT for 90% shelter occupancy. (Compare upper two curves.) The difference is less at lower attack levels and at lower occupancy.

5. All U.S. blast shelters are constructed for 100 psi in the city

[redacted]

center and 30 psi in the suburbs. This is Case "5B" in the OCD study. Of all the OCD Blast Shelter postures studied, this one consistently gave the highest percent surviving for equal cost.

6. For the case where blast shelter protection is provided for 100 cities (U.S. cost -- $43.1 B), population is protected as follows:

OCD Rated Overpressure 1/	Mean Lethal Overpressure 2/	Protection Factor 3/	Potential % U.S. Population Sheltered
Blast Shelters:			
100 psi	136 psi	5000	22%
30 psi	42 psi	1000	34%
Fallout Shelters:			
(4 psi)	10 psi	250	31%
(4 psi)	10 psi	57	13%

1/ Rated overpressure, as used in OCD study, is that overpressure at which there is a 95% probability of a sheltered person's surviving.

2/ Mean Lethal overpressure is that overpressure at which there is a 50% probability of surviving.

3/ Protection factor is the ratio of the radiation level outside the shelter to the radiation level inside.

Basic Points

7. There is high utility in fallout shelter programs. Over a wide range of attacks on cities (2000 - 10,000 MT in addition to

[redacted]

2500 MT on military targets), the Full Fallout (FFO) Shelter program saves about 24% of the total U.S. population.

8. After the FFO shelter program, Civil Defense shows strong diminishing returns. For example in going from the case where 23 cities have blast shelters to the case where 100 cities have blast shelters costs about $12 B and saves an additional 4 - 5% of the U.S. population over a wide range of attacks.

9. An additional 10% U.S. population would survive if blast shelters were occupied by 90% of the population as compared to 50% occupied. This holds over a wide range of attacks when 100 U.S. cities are protected. If the Soviets targeted on the basis of shelter rated overpressure rather than 10 psi, there would be about 5% less population surviving.

[redacted]

Figure 4

% U. S. Population Saved by U. S. FFO Program
vs
Soviet MT on U. S. Military Targets for Various
MT on U. S. Urban Targets (Population)

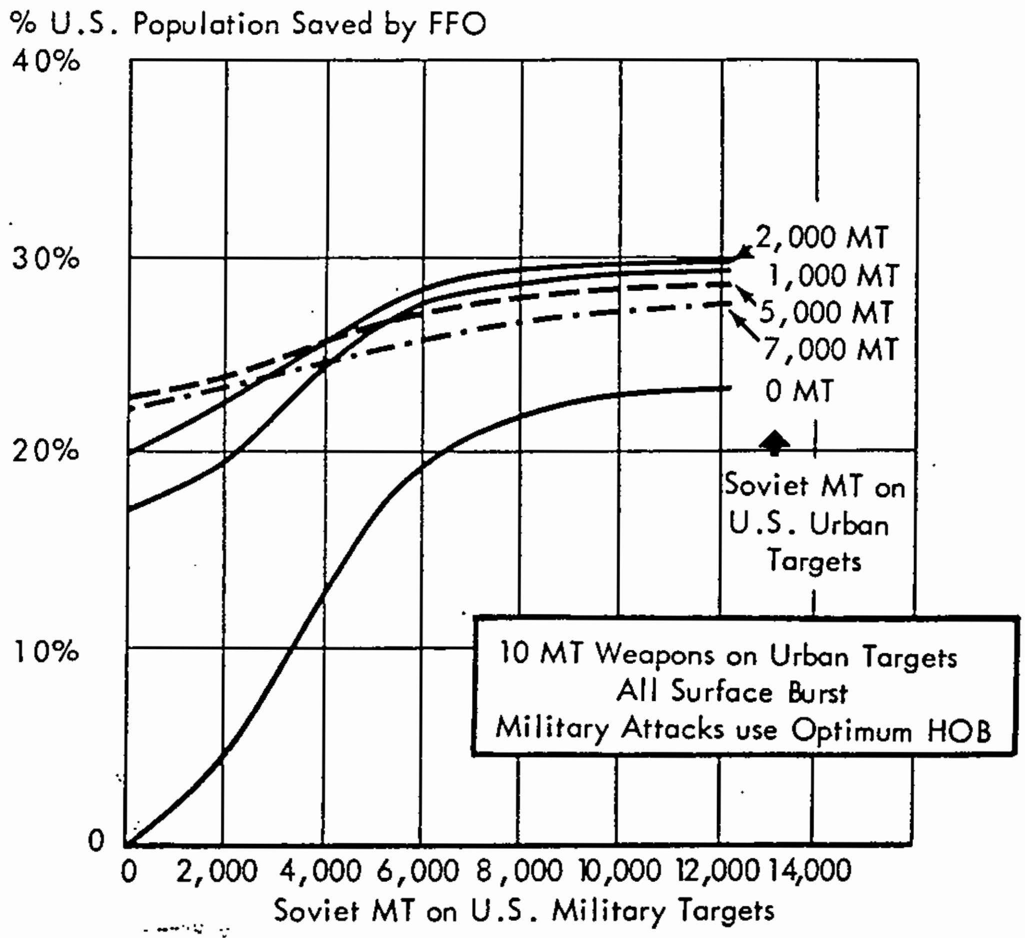


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Figure 4

% U.S. POPULATION SAVED BY FFO SHELTER PROGRAM vs SOVIET MT ON U.S. MILITARY TARGETS

FOR VARIOUS MT ON U.S. URBAN (POPULATION TARGETS)

Purpose

1. To show the utility of the U.S. Full Fallout Shelter program for a wide range of military and urban attacks.

Basis for Computation

2. Soviet weapons used on U.S. urban targets are 10 MT each, all surface burst.

3. Soviet military attacks are designed for optimum height of burst against each target being attacked. Restraint is used in the sense of avoiding military targets co-located with major urban areas.

4. Data used are damage runs of Figure 3 and supplementary excursions.

Basic Points

5. Between 20% and 30% of the U.S. population (40 - 60 million people) are saved by the FFO shelter program for a wide range of Soviet attacks against military and/or population targets.

6. As an example, 20% of the U.S. population is saved by FFO for the following combinations of Soviet attacks:

MT on Military Targets	MT on Population Targets	% Surviving Total Population *
6400	0	90%
2500	1000	70%
0	2000	67%

* With FFO

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Figure 5

% U. S. Population Surviving
vs
Cost of U. S. BMD/TBD/FFO
for
Three Levels of Soviet Missile Attack on U. S. Cities

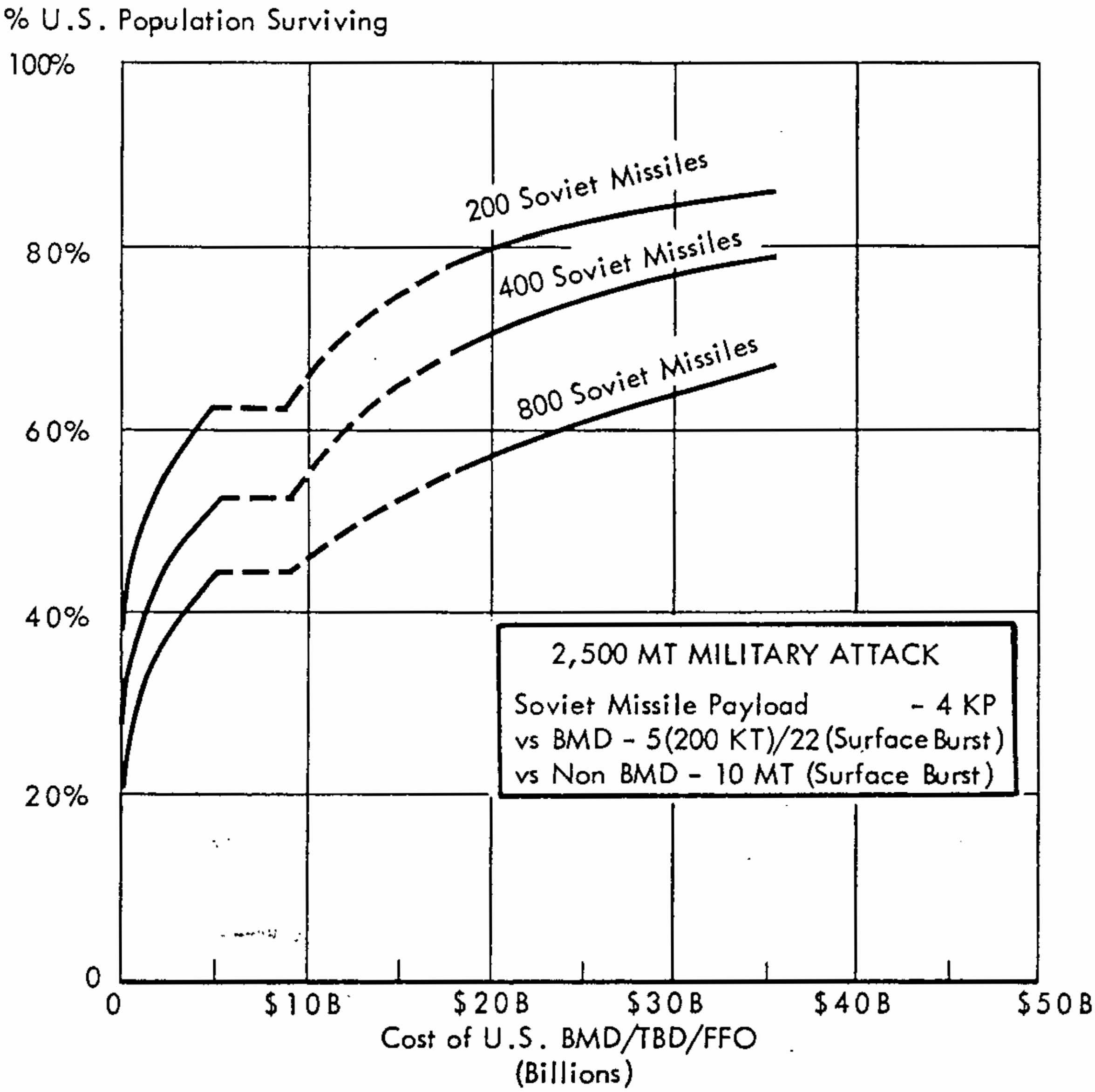

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Figure 5

% U.S. POPULATION SURVIVING vs. COST OF U.S. BMD/TBD/FFO
FOR THREE LEVELS OF SOVIET MISSILE ATTACK ON U.S. CITIES

Purpose

1. The purpose of this graph is to display the relative utility of combined U.S. Ballistic Missile Defense (BMD), Terminal Bomber Defense (TBD) and a Full Fallout Shelter Program (FFO) in saving U.S. population. This has been done for three Soviet attack sizes.

Basis for Computation

2. The curves were derived from the Army and OCD studies.

3. U.S. TBD Costs were computed by first deploying HERCULES/HAWK batteries to prevent serial bombing of U.S. cities by Soviet bombers. (This effect is shown later in Figure 14.) As BMD was deployed sequentially, in (up to) 96 U.S. cities, the HERCULES/HAWK batteries in the BMD defended cities were replaced by the more sophisticated AADS-70 in order to prevent bombers from undercutting the BMD (NIKE-X).

4. Sufficient AADS-70 was deployed in NIKE-X defended cities so that a U.S. city target was never more attractive to a Soviet bomber than to a Soviet missile. The Army study shows that this "balanced interlocking" of TBD and BMD can be achieved by expending an additional 20% -- additional over NIKE-X expenditures -- on AADS-70 in the same cities.

[redacted]

5. The flat portion of the curves begins when a full fallout shelter program has been bought and ends when R&D costs for BMD/TBD and $1.0 B for HERCULES/HAWK batteries have been expended. In a sense, then, these curves do not display the optimum way of expending funds at every point on the curves. For example, if the planner were to spend $7 B, he could attain a slightly higher % U.S. surviving than shown, but he could not, at the same time, accomplish the necessary R&D to deploy BMD.

6. Soviet missile payload is 4 kilopounds. A single 10 MT warhead (surface burst) is used against undefended (undefended by NIKE-X) cities. Five 200 KT warheads (surface burst) plus 22 indiscriminable decoys are used against defended cities.

7. The computations assume the Soviets have complete knowledge of the defenses; by either avoiding or attacking the defenses the Soviets always target for maximum U.S. population killed.

8. The indicated attack is in addition to a 2500 MT Soviet attack on U.S. military targets.

Basic Points

9. An expenditure of $25 B for BMD/TBD would increase the percent U.S. population surviving from about 52% to about 77% against a constant threat of 400 Soviet missiles.

10. BMD/TBD/FFO utility shows strong diminishing marginal returns in terms of increase of percent surviving with increasing expenditures.

[redacted]

11. The change in marginal U.S. cost per percent U.S. population surviving is relatively independent of the size of the Soviet missile attack (i.e., the utility curves are almost parallel).

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Figure 6

% U.S. Population Surviving vs Cost of U.S. BMD/TBD/FFO or U.S. Blast/FFO for Two Levels of Soviet Attack

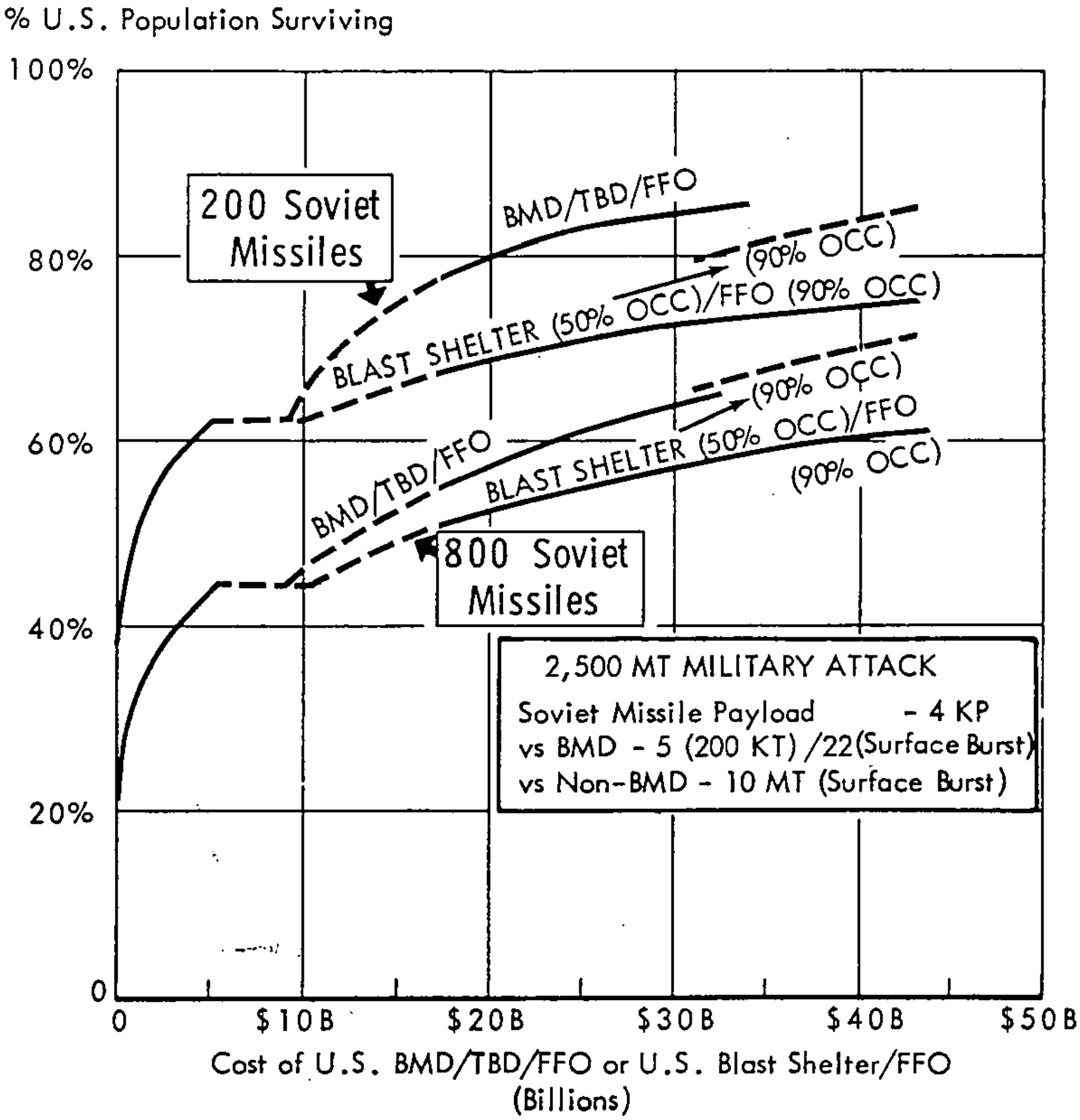

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Figure 6

% U.S. POPULATION SURVIVING vs. COST OF U.S. BMD/TBD/FFO OR U.S. BLAST/FFO FOR TWO LEVELS OF SOVIET ATTACK

Purpose

1. This graph compares the relative utility of U.S. active and U.S. passive defenses -- each in addition to FFO shelter program -- in saving U.S. population for two cases of Soviet attacks.

Basis for Computation

2. 50% occupancy of U.S. blast shelter spaces were considered. 90% of the population was assumed to have fallout protection.

3. Soviet attack is by means of 4 KP missiles on cities. Against BMD defended cities, the Soviet missile payload consists of five 200 KT (surface burst) warheads plus 22 indiscriminable decoys. Against blast shelter defended cities, the Soviet payload consists of one 10 MT warhead (surface burst).

4. The BMD/TBD/FFO curves are the same as those in Figure 5.

5. The flat portion of the Blast Shelter/FFO curve includes costs for R&D, Warning, Command Control, and Support costs for the Blast Shelter/FFO case. These cost breakdowns were obtained from the OCD study.

6. The indicated attack is superimposed on a Soviet 2500 MT attack on U.S. military targets.

7. The effect of a higher occupancy rate for blast shelters is displayed by the dashed curve. This curve represents the %

[redacted]

U.S. population surviving if blast shelters are deployed and if the blast shelter spaces are 90% occupied.

Basic Points

7. Active defense with a FFO shelter program saves more U.S. population than purely passive defense systems (Blast Shelters/FFO) when blast shelters are occupied at a 50% rate.

8. When blast shelters are occupied at a 90% rate, BMD/FFO is less effective at high Soviet attacks.

9. Data from the OCD study showed that, for a wide range of attack sizes, a mixed BMD/Blast Shelter Posture (e.g., first 23 cities defended by NIKE-X, cities 24 - 100 having blast shelters) is more effective, for a given cost, than blast shelters alone and approximately the same effectiveness as for BMD alone.

10. Some preliminary analysis showed that some carefully tailored blast shelter designs mixed with BMD might be more effective than BMD alone -- this mix involves blast shelters in smaller cities not necessarily defended by BMD. Sufficient data was not available to pursue this analysis.

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Figure 7
% U.S. MVA Surviving vs Cost of U.S. BMD/TBD/FFO or Blast Shelters/FFO for Two Levels of Soviet Attack

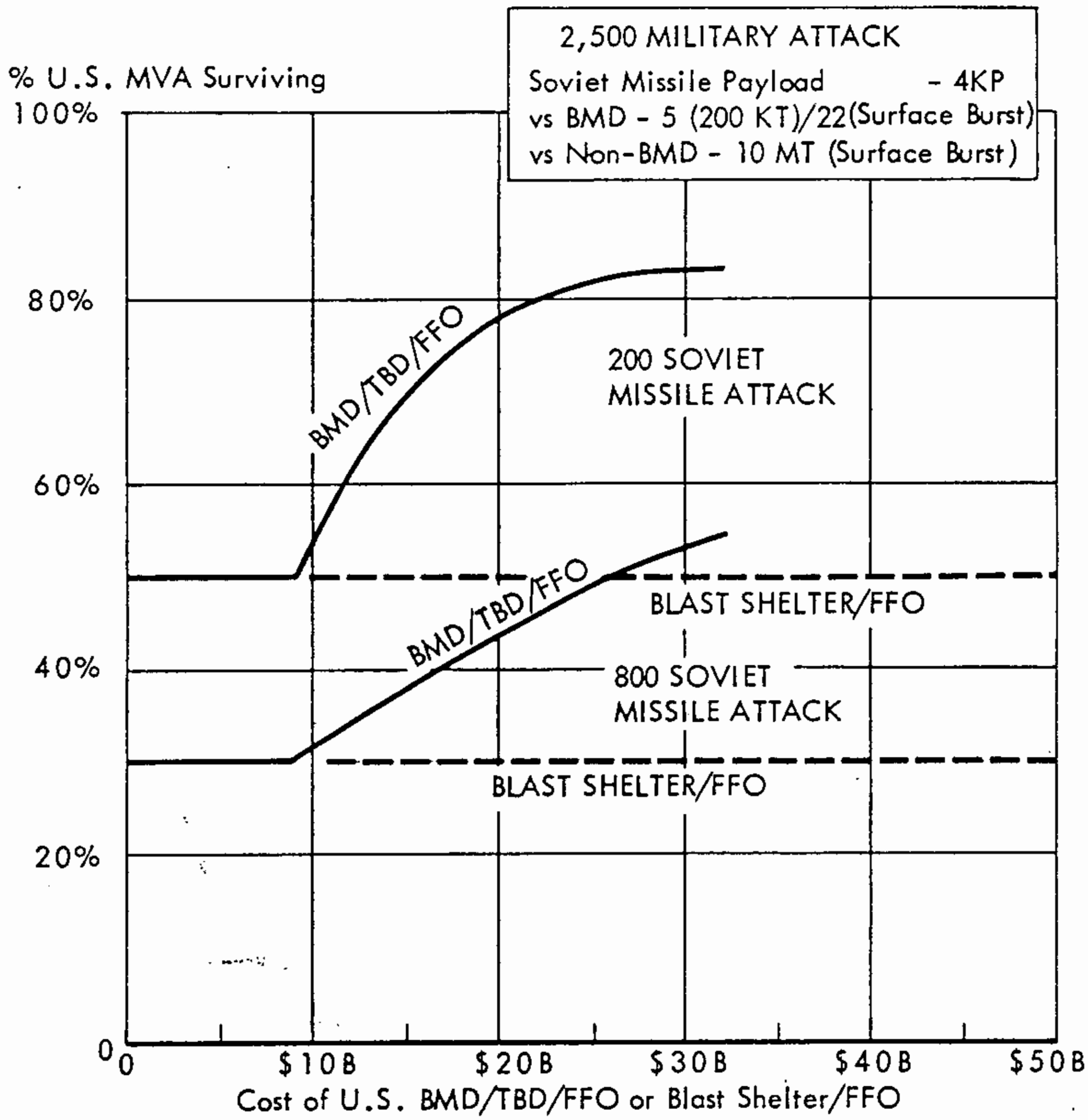

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Figure 7

% U.S. MVA SURVIVING vs. COST OF U.S. BMD/TBD/FFO OR BLAST SHELTERS FOR TWO LEVELS OF SOVIET ATTACK

Purpose

1. This graph shows the relative utility of active and passive defenses in saving U.S. MVA.

Basis for Computation

2. Soviet missiles have payloads of 4 KP as described in paragraph 3 of Figure 6.

3. Percent MVA surviving is computed using Figure 5 and the population/MVA correlation of Figure 2.

Basic Points

4. Passive defensive measures are not useful in saving U.S. MVA.

5. At high levels of U.S. defense and for expenditures of $10 B or more above a FFO program, active defense can save from 20% to over 30% of the U.S. MVA.

6. The initial rate of increase in U.S. MVA surviving is much steeper at lower levels of Soviet attacks. This stems from the fact that the U.S. active defenses are deployed first in the higher worth U.S. cities which contain a high percentage of U.S. MVA. But as the Soviet attack increases, the Soviets are paying the price to attack these high worth, highly-defended cities and the rate of increase in percent U.S. MVA surviving, for a given U.S. expenditure, is not as large.

[redacted]

7. Active defense serves to destroy weapons before impact, while passive defense (CD) negates their effects after impact. This negation before impact aids U.S. recovery -- some cities may be left intact and the post attack environment may be less severe.

NOTE: On the basis of this and the previous graph, it was concluded that active defense together with the full fallout shelter program is a more useful deployment for the U.S. than a program of purely passive defense. Only computations involving BMD/TBD/FFO are carried forward in the remainder of the study.

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Figure 8

Reliable Soviet ICBM Payload (in KP) Surviving
vs
Number of Reliable R/V's in U.S. SOF
for a
$12B Soviet ICBM Budget and for Various
Soviet KP per Missile Packaging

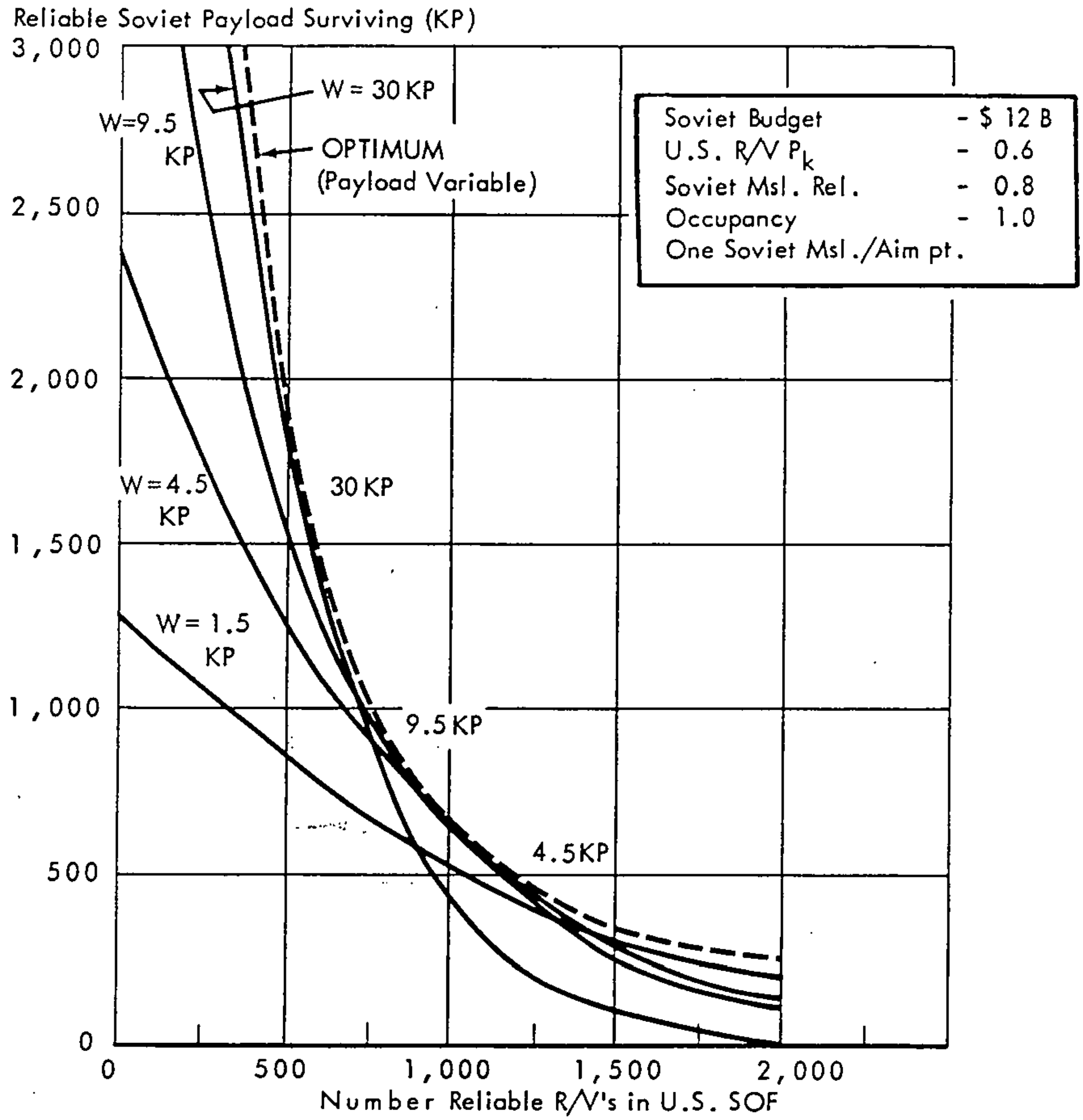

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Figure 8

RELIABLE SOVIET ICBM PAYLOAD (IN KP) SURVIVING vs. NUMBER OF RELIABLE RE-ENTRY VEHICLES IN U.S. STRATEGIC OFFENSIVE FORCES FOR A $12 B SOVIET ICBM BUDGET AND FOR VARIOUS SOVIET KP/MISSILE PACKAGING

Purpose

1. This graph shows the posture of the Soviet fixed-base ICBM second strike capability which survives a U.S. Strategic Offensive Force (SOF) attack.

Basis for Computation

2. Four payload deployments of the Soviet ICBMs were examined, 1.5, 4.5, 9.5 and 30 KP payloads corresponding approximately to the Soviet ICBMs, SS-X-1, SS-7/8, SS-9, and SS-10 respectively. One U.S. SOF R/V was applied to each Soviet missile site, then a second on each site and then a third and so on.

3. Each reliable U.S. SOF R/V has a SSP_k of 0.6. For example, this corresponds to a [redacted]

4. The number of Soviet missiles surviving the U.S. SOF attack are reduced to 80% for reliability and then converted to KP at the individual KP of the appropriate missile examined.

5. The Soviet budget is constrained at $12 B throughout the computation.

[redacted]

6. The envelope of all possible Soviet KP per missile deployments is plotted and marked "optimum (payload variable)". This curve represents the maximum Soviet KP surviving if the Soviets packaged KP per missile in the optimum way opposite a given U.S. SOF threat.

7. It was found that the cost of Soviet ICBMs could be fit by ANW^k where A is $10 M per 1 KP missile in inventory ($12.5 M per reliable missile), N is the number of Soviet missiles, W is the payload per missile in kilopounds (KP), and k = .4.

Basic Points

8. Opposite small numbers of R/Vs in the U.S. SOF inventory, the Soviets optimum tactic is to deploy large payload per missile packages to maximize KP surviving a U.S. SOF attack. Opposite large numbers of U.S. R/Vs the optimum Soviet tactic is to deploy small payloads per package.

9. At other than optimum packaging, the Soviet ICBM KP surviving will be less than is shown by the graph opposite a given U.S. attack. For example, if the U.S. has about 1000 reliable R/Vs in SOF and the Soviets spend $12 B, about 700 Soviet KP will survive a U.S. SOF attack if the Soviets are optimally packaged (about 6 KP per missile); whereas, for the same budget, if the Soviets deploy in 30 KP per missile packages, only 400 KP will survive the same U.S. attack.

10. It turns out, for the planning assumptions used, that when the Soviet is optimally deployed, about 22% of his missiles will

survive a U.S. SOF attack. Said another way, the Soviet optimal deployment provides enough aim points so that, for a given U.S. SOF, the U.S. can apply about 1.6 R/V, on the average, per Soviet aim point.

11. Mixtures of payloads (at the same total budget) generally fall between the pure, single KP curves shown. It is important to note that the single payload curve or mixed cases are close to the optimum curve over a broad range -- i.e. the payload surviving is not too sensitive to packaging over a broad range. Therefore, the optimum solutions carried forward are a good approximation to a variety of special cases.

12. The results on this chart are not sensitive to the choice of U.S. SSP_k in the following sense: An examination of warhead technology reveals that repackaging of a fixed total U.S. payload into a smaller (larger) number of heavier (lighter) R/Vs -- with corresponding larger (smaller) SSP_k -- has virtually no effect on these results, so long as (1) the U.S. CEP and (2) Soviet hardness are kept fixed and so long as (3) at least one reliable U.S. R/V impacts on each Soviet aim point.

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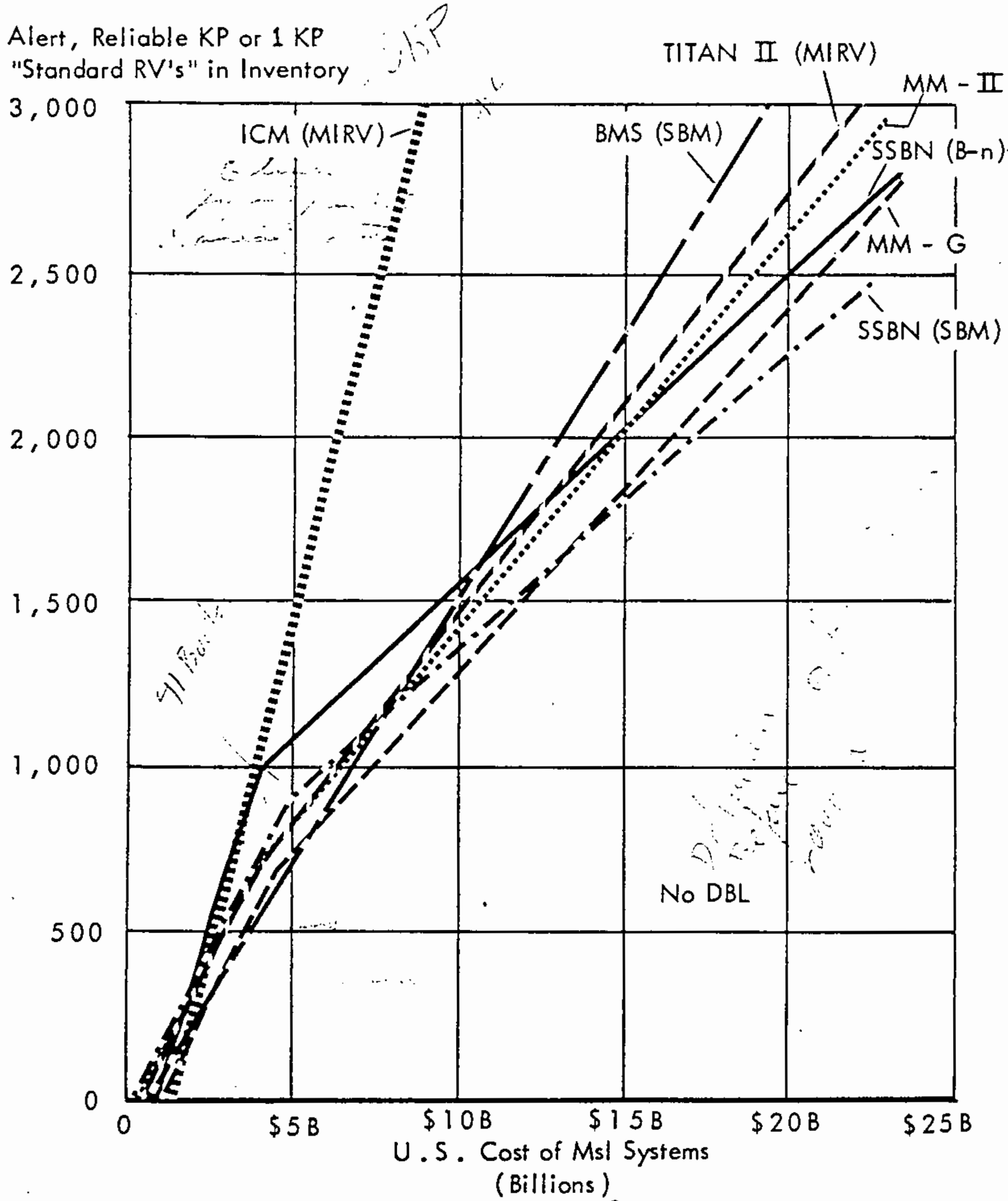
Figure 9

Alert, Reliable KP or "Standard 1 KP RV's" vs U. S. Cost



Only the slope of the line is significant

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Figure 9

ALERT, RELIABLE KP OR "STANDARD 1 KP R/Vs" vs. U.S. COST

Purpose

1. To show the comparative costs of various SOF missile systems in terms of KP or 1 KP standard R/Vs.

Basis for Computation

2. Systems data are from the Navy and Air Force studies.

3. Operational factors used are nominal values.

	Alert/On Station	Alert Readiness Reliability	Launch Reliability	In-flight Reliability	Nominal Operational Factor
MM, ICM	.9	.95	.9	.9	.69
SLBM	.6[1]	.95	.9	.9	.46[1]
TITAN	.9	.95	.85	.8	.58

[1] With Strategic Warning, increase Alert/On Station to 0.8, operational factor to .61 (The case for No Strategic Warning was used in the graph).

4. To normalize systems to 197x technology, payload (KP) was used as a systems measure. The same packaging and guidance technology are available to all systems in this time period. This payload may be divided en-route to targets (MIRVs), so that a standard 1 KP R/V can be used to convert to nominal U.S. Cost/R/V. MM and SBM payloads were normalized to 1 KP. Later SSP_k calculations take into account actual CEP/payloads.

5. No attrition before launch is included.

[redacted]

Basic Points

6. Partly because of "sunk costs" (for example, 41 POLARIS boats already bought) -- the curves (with the exception of the ICM) for various systems tend to cluster.

7. Above 500 standard R/Vs, the spread is greater. However, it should be noted that:

   a. If the exact KP/MM were put in, it would raise the MM curves slightly above all but the ICM (lower cost per KP).

   b. If shorter range were traded for increased payload or if sea-based systems have strategic warnings, the curves for the sea-based systems would be raised (lower cost per KP).

   c. If amortized costs had been used -- amortized costs are used in this study for trade-off purposes -- the cost/R/V of the various systems would be closer together.

   d. Listed below are the relative survivabilities at which the cost/R/V of all systems are equal to the POLARIS systems. Another factor in survivability (by proliferation), which drives the Soviet SOF budget, is the number of aim points presented the Soviets per KP deployed. Figures for this are also shown for each system:

[redacted]

SYSTEM	Relative Survivability for Equal Cost	Number U.S. Aim Points per 1000 "Standard R/V's" Deployed
POLARIS B-n, SBM	1.0	0 (20)
TITAN II	.76	105
BMS	.56	0 (20)
MM II	.70	1000
MM-G	.75	1000
ICM	.47	133

(The numbers in parentheses are numbers of ship or boat targets for Soviet ASW).

8. For the above reasons, the analysis of "standard" systems (excluding very low CEPs which are treated separately) will use MINUTEMAN II cost data as representative of this class of SOF systems without specifically referring to competing types of missiles (U.S. SOF in a general sense).

9. In Figure 9 ICM stands out in the case of no Destruction Before Launch (DBL). The cost difference between ICM and MINUTEMAN at constant inventory KP is, in a sense, the amount of money that could be spent on hard point defense of ICM in order to reduce DBL. Data on hard point defense of missile sites was not included in the Service Studies and is omitted from this study.

SOF Utility of Advanced Systems

CEP Reduction

11. It is predicted that CEPs as low as 1000' will be technically feasible by the middle 70's. This technology of low CEPs permits one to achieve SSP_k's of .90 even for hard targets (300 psi) with an R/V weight of 1000 pounds or less.

12. In examining the relative utility of SOF with other means of limiting damage, the cost to negate or destroy a kilopound of Soviet payload is an appropriate measure of the (marginal) utility. For SSP_k - .90, this marginal cost is the cost per reliable R/V -- C_R -- divided by the expected payload destroyed by the R/V:

	1st R/V/target	2nd R/V/target
Cost/KP negated:	$\frac{C_R}{.9\ (KP)\ tgt*}$	$\frac{C_R}{.09\ (KP)\ tgt*}$

The Marginal Cost of destroying Soviet KP of the second R/V target is thus 10 times that for the first. This applies to weapon systems where it is not possible to assess the results of the first weapon -- no shoot-look-shoot (see Figure 11).

* (KP) tgt. is simply the Soviet kilopounds deployed at each aim point.

13. In most trade-offs this results in a fairly sharp break -- one reliable R/V per target is very competitive with other means of limiting damage and the second R/V per target is not.

Multiple Individually Targeted Re-entry Vehicle (MIRV)

14. The ability to break up a missile payload into Multiple Individually Targeted Re-entry Vehicles (MIRV) allows further capitalization on low CEP technology. If only a single re-entry vehicle (R/V) were possible, then one U.S. missile in inventory could, obviously, kill no more than one Soviet target, no matter how small the CEP became. With MIRV technology the U.S. missile payload may be split up and can, with a low enough CEP, kill more than one Soviet target. Furthermore, MIRVs can be applied to large payload missiles, ICM and B-n for example, in which payload can be deployed more cheaply than in smaller missiles. Thus the combination of low CEP and MIRVs on large boosters allows the U.S. to deploy significantly more R/Vs of a given kill probability for a given U.S. budget.

15. Figure 8 discussed one Soviet second strike design that responds to increasing numbers of U.S. R/Vs, namely, the balanced proliferation of optimum payload ICBMs. There are other possible responses: active defense of missile sites, land-mobile missiles and sea-based missiles. None of the Service studies addressed the question of active defense of missile sites and, consequently, it is omitted from this study. The one land-mobile missile reported by the Air Force study was not competitive with balanced proliferation. Soviet

sea-based missiles will be considered explicitly.

16. For both the U.S. and Soviet, MIRVs weighing 1 KP are carried forward for sea-based systems. Large payload ICBMs with MIRVs present a serious counterforce threat which, however, when undefended, are fairly vulnerable to attack. Because of this, and because no data was available on active missile site defense, large payload ICBMs with MIRVs were not carried forward for either the U.S. or the Soviet.

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Figure 10

Reliable Soviet ICBM KP Surviving
vs
Cost of U. S. SOF for Various Soviet Budget ICBM Levels

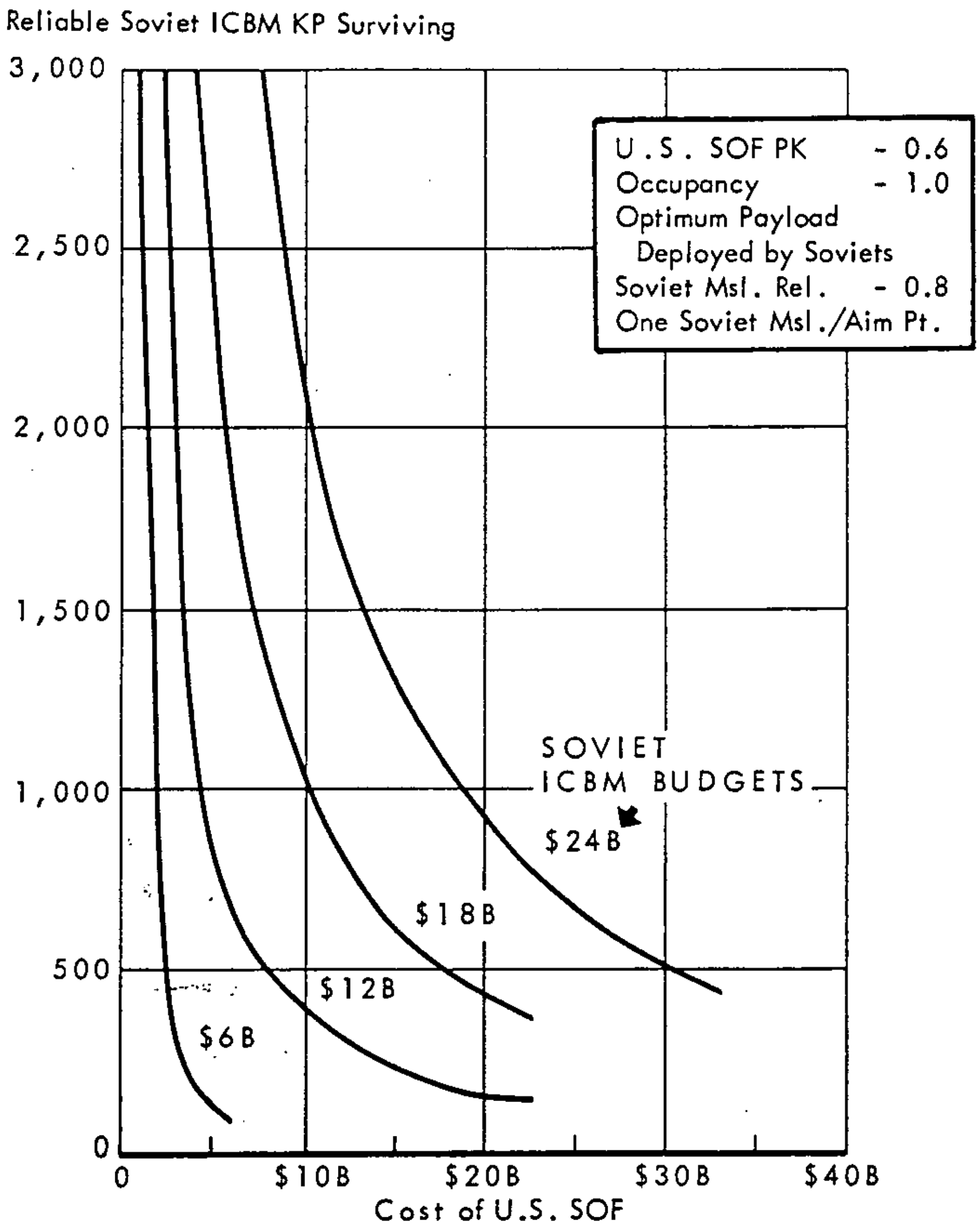

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Figure 10

SOVIET ICBM KP SURVIVING vs. COST OF U.S. SOF
FOR VARIOUS SOVIET BUDGET ICBM BUDGET LEVELS

Purpose

1. The purpose of this graph is to display the maximum number of Soviet ICBM KP surviving for a given Soviet ICBM budget when faced with a given U.S. expenditure on SOF. On this graph, the Soviets are optimally deployed in terms of the optimum size package.

Basis for Computation

2. Optimum deployment curves have been derived for various Soviet ICBM budgets in the manner described for the optimum curve of Figure 8. (The same planning factors inherent in Figure 8 are used here). One Soviet missile per aim point is assumed. Cost of U.S. SOF is the representative cost referred to in Figure 9.

Basic Points

3. For a given U.S. SOF expenditure and attack, there is a maximum Soviet ICBM payload surviving for each level of Soviet ICBM budget. For example, for a U.S. $18 B SOF deployment, the maximum Soviet ICBM KP that can survive, if they also expend $18 B, is about 500 KP if the Soviets have optimally packaged their KP/missile.

4. Opposite a given U.S. posture, any Soviet warhead packaging other than optimum will result in less Soviet kilopounds

surviving.

5. The existence of U.S. SOF provides a "virtual" attrition of Soviet KP even in Soviet first strike where U.S. SOF does not have an opportunity to operate on Soviet KP prior to its launch against U.S. cities. It turns out from the manner in which the accompanying curves were derived that the Soviet KP inventory is about 4.5 times the Soviet KP surviving. If the U.S. spends $2 B on SOF and the Soviets wanted 1000 KP surviving in second strike, they would have to spend $6 B. They would have 4500 KP in inventory for a cost rate of $1.33 M per KP deployed. With this relatively small U.S. SOF threat the Soviets can afford to deploy very large missiles which have a lower cost per KP deployed than smaller missiles. On the other hand, if the U.S. spends $10 B on SOF, the Soviets must spend $18 B to have 1000 KP surviving. The cost per KP deployed is now $4 M per KP. This is to be compared with $1.33 M for the previous case. Thus there is a "virtual" attrition with increasing U.S. SOF -- even in Soviet first strike -- in that the Soviet cost per KP deployed is much higher if they consider their second strike posture -- which they must.

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Figure 11

MARGINAL COST PER REL KP DESTROYED BY ICBM AND/OR AIRCRAFT ATTACK ON USSR ICBM SITES

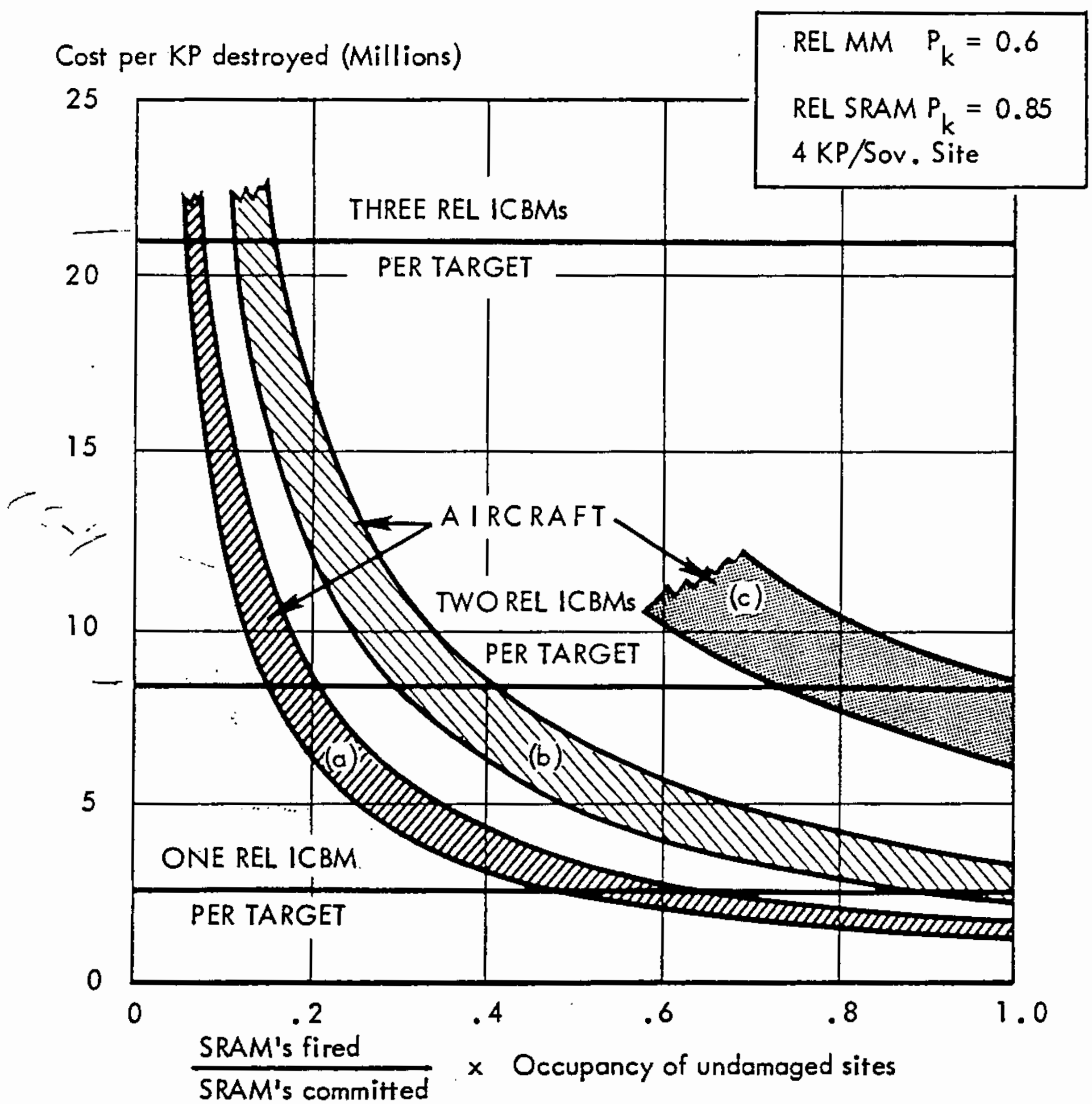

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Figure 11

MARGINAL COST PER RELIABLE SOVIET KP DESTROYED BY ICBM AND/OR AIRCRAFT ATTACK

Purpose

1. To compare ICBMs with aircraft carrying Short Range Attack Missiles (SRAM) in a damage limiting role as a function of the marginal cost per enemy unit payload (KP) destroyed.

Basis for Computation

2. The comparison is made parametrically with respect to the product of two factors. The first factor, the mean penetration, accounts for aircraft attrition enroute to and between targets. The mean penetration is defined as the ratio of (a) the SRAMs fired against either missile sites or terminal bomber defenses (but not air-to-air against interceptors) to (b) the number of SRAM arriving at the Soviet Area Bomber Defenses that are committed to the missile site mission. The second factor is the occupancy, at the time the bombers arrive, of those missile sites that were not killed by the prior ICBM attack.

3. Three cases of Terminal Bomber Defense with Surface-to-Air Missiles (SAM) were examined. It is assumed that the SAM sites are located beyond the lethal radius of the ICBM attacking the primary target.

4. In case (a) there are no SAM defenses. The aircraft assesses which missile sites are undamaged and delivers one reliable

SRAM (P_k = .90) on each undamaged site.

5. In case (b) each missile site is defended by one HAWK-type platoon, but the aircraft can assess the target without coming within range of the SAM site. Based on the Army study, a HAWK platoon can destroy one of two SRAMs launched simultaneously. Thus in case (b) two SRAMs are launched at each <u>undamaged</u> missile site. The SAM shoots down one SRAM and the other SRAM strikes the missile site (P_k = .9).
6. In case (c) each missile site is defended but the aircraft must use two SRAM to suppress the SAM site in order to come within range to assess the target. In case (c) the best aircraft tactic is to avoid the defense and directly attack <u>all</u> missile sites with two SRAM each without attempting to assess whether the site is undamaged. As in case (b) one SRAM gets shot down but the other strikes the target.
7. The Soviet missiles have 4 KP payload, are 80% reliable and are deployed one missile per site.
8. The U.S. ICBM is the MINUTEMAN II type with 60% single-shot kill probability, 69% deliverable to target and completely re-targetable for non-deliverables. U.S. ICBM costs (amortized) were based on MINUTEMAN II force levels of 1000 ($3.5 B), 2000 ($8.0 B) and 3000 ($12.5 B) missiles for programming ratios of one, two and three reliable U.S. missiles per Soviet site, respectively.
9. The U.S. aircraft are the AMSA and RS-52 (B-52 with SRAM and

[redacted]

advanced avionics) types with 18 SRAMs, 85% reliable with a 90% single-shot kill probability against the hard targets and are retargetable for weapons failing to reach target. AMSA costs (amortized) were based on a force of 200 ($9.0 B, 67% launched, 90% in-flight reliability); RS-52 costs on a force of 315 ($7.76 B, 52% launched, 90% in-flight reliability).

10. The horizontal lines represent U.S. costs per kilopound of Soviet payload destroyed for ICBM attacks with programming ratios of one, two and three reliable missiles per target, respectively.

11. The curves represent aircraft attack; the spread caused by the different costs and alert rates for the two types of aircraft. A pure RS-52 force is shown on the lower curve and a pure AMSA force on the upper curve. It is important to note that for the <u>same</u> area bomber defense the AMSA has a higher mean penetration than the RS-52. For the <u>same</u> situation different values of the abscissa apply to the two aircraft. Aircraft curves (a), (b) and (c) correspond to the different defense assumptions described in paragraph 2 above.

12. Aircraft curves (a) and (b) can be compared with all of the three ICBM programming ratios. The results from defense assumption (c) are shown only for the case where there has been one missile programmed against each target, and the comparison is made between a second ICBM <u>or</u> follow-up aircraft attack.

[redacted]

Since, in case (c) the KP destroyed depends on the amount of prior ICBM attack, separate aircraft curves are associated with different ICBM programming ratios.

13. The cost to the enemy to defend an ICBM site(s) with a HAWK-type platoon would be about $7 million (amortized 5-year cost). He could buy and support an additional, undefended, ICBM for the cost to defend two sites.

14. On the basis of curve (a) for no SAM defense an initial programming of one reliable U.S. ICBM per Soviet ICBM site followed by look-shoot aircraft has a lower marginal cost than two U.S. ICBMs per site for values of the abscissa (mean penetration times occupancy of undamaged sites) above about .2. For values of the abscissa above 0.6 aircraft are preferred over initial ICBM attacks.

15. On the basis of curve (b) for SAM defenses that did not restrict target damage assessment, one ICBM followed by aircraft has a lower marginal cost than two ICBMs for values of the abscissa above about 0.4.

16. On the basis of curve (c) for SAM defenses that restricted target damage assessment, one ICBM followed by aircraft has a higher marginal cost than two ICBMs except at values of the abscissa approaching unity.

17. If the Soviet chose to defend ICBM sites against aircraft attack it would have the virtual effect, for the same budget,

of reducing the Soviet deployed payload by about one-third. However, this defense more than doubles the marginal cost of the bomber attack if the bomber can assess the target without engaging the defense, and makes the aircraft non-competitive with a second missile if it must engage the defense of each site. In some sense, the probability of high occupancy is related to the level of SAM defense.

18. It is important to note that there exists some level of defense, when it is no longer the bomber's best option to engage the defense and employ look-shoot tactics. (See paragraph 6 above).

19. Due to the uncertainties in occupancy of Soviet sites when aircraft arrive, in the mean penetration, and in the nature and deployment of defenses of Soviet missile sites, only missile SOF will be carried forward in the analysis. The results here show that there is a range of parameters for which an aircraft follow-up attack would compete with the second missile.

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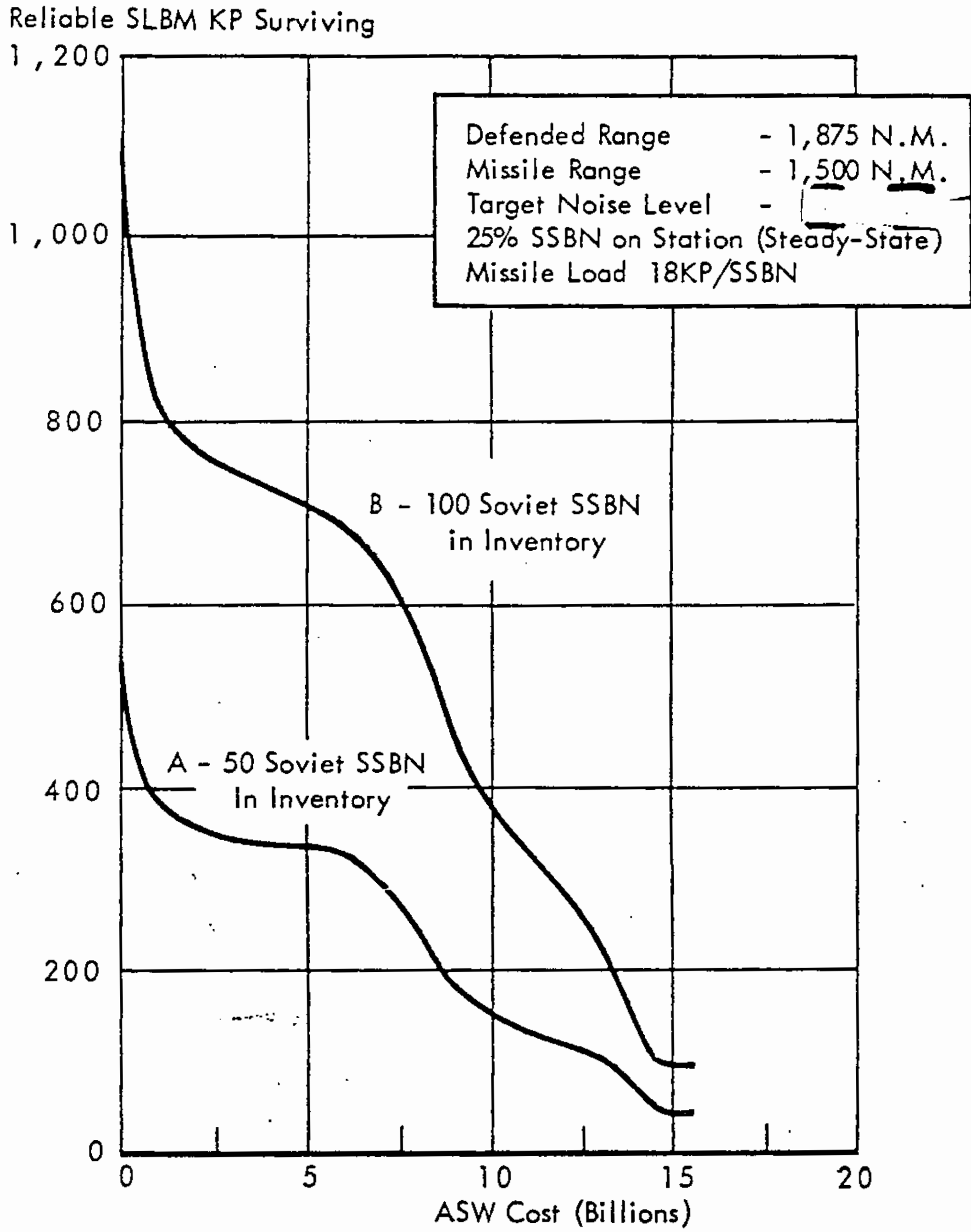
Figure 12

Reliable Soviet SLBM KP Surviving vs U.S. Cost of ASW



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80-FOI-985 (3)

Figure 12

SOVIET SLBM KP SURVIVING vs U.S. COST OF ASW

Purpose

1. To show the utility of combined ASW forces operating against a Soviet POLARIS-type deployment.

Basis of Computation

2. Basic data and system capabilities in the 197x time frame are from the Navy study.

3. The Soviet SSBN is assumed to have a [redacted] noise level*, 12 launch tubes each containing 1.5 KP missiles with a 1500 n. mile range and 0.8 reliability. Excursions on these parameters will be treated in later sections.

4. This graph results from a series of sub-optimizations of various types of forces operating against the total potential SLBM threat. These types of forces are:

a. Forces deployed on a steady-state basis in the launch area operating against Soviet POLARIS-type submarines on station. These are Navy study's "Condition III" forces -- essentially destroyer attack units, with SOSUS. These forces trail on-station Soviet submarines, fire on

[redacted]

emerging missiles, and sink the boat which launched them. Navy air forces are used to establish (and regain, if lost,) contacts for trailing.

b. Forces which are deployed (which include part of those in a.) to meet additional submarines that attempt transit to the launch area after the war begins. These are Navy study's "Condition I" forces -- essentially Navy air forces which follow-up SOSUS contacts and destroy submarines in a "defended area" (barrier) outside the launch area.

c. Forces (SSNs) deployed in forward barriers to destroy Soviet submarines exiting from port areas. Some of these forces also trail Soviet submarines across the ocean.

d. Forces (SOF) operating on Soviet SSBNs in overhaul or still in port.

5. Two Soviet force levels are considered with the same steady-state deployment scheme. Curve A represents 50 SSBNs in the Soviet inventory and Curve B 100 SSBNs. The appropriate deployment for Soviet steady-state was estimated to be 15% in overhaul, 45% in port or local operating areas, 15% in transit, and 25% on-station. About 20% of the inventory is assumed destroyed by SOF operations.

6. Equal numbers of submarines and equal allocations against them were made for the Atlantic and Pacific Oceans. Because of geographical asymmetries in the operation and cost of ASW between the two oceans, the U.S. could do somewhat better

allocating against particular known divisions of the threat to population and comparing the return per dollar in each ocean. In this respect, the results shown here are somewhat conservative with regard to the utility of ASW in damage limiting.

Basic Points

7. The first large decrease in Soviet SLBM KP surviving results from the increased tempo of operations of exixting ASW forces - - surface, air and the SSN barrier. Though the Soviet submarines attrited in this area constitute a threat that develops later in time than those Soviet SSBNs already on-station, the sub-optimization is made against the total threat. The fact that most of the U.S. SSNs operating the barrier have already been funded in pre-FY 66 budgets affects this result.

8. The behavior of the curve at higher U.S. expenditures shows the complex behavior of various "entry-prices" -- such as buying enough SOSUS.

9. The curves show that for about $14 billion allocated to ASW, the major part of the SLBM threat from a Soviet POLARIS-type operation can be negated and that this budget is somewhat independent of Soviet force size.

10. Excursions to other deployments and scenarios were made but not included here. Depending on which situations the U.S. prepared for, sub-allocations to individual ASW forces would change. However, total ASW budgets in support of damage limiting would not alter appreciably. A limiting case for "perfect" Soviet submarines -- no utility for ASW -- is treated on Figure 27.

[redacted]

Figure 13

% Soviet Bombers Killed by Area Bomber Defense
vs
Inventory of Interceptor Aircraft (IMI)

DEFENSE SUPPRESSION
70 Soviet ICBM's
30 Long Range ASM's Carried by Bombers

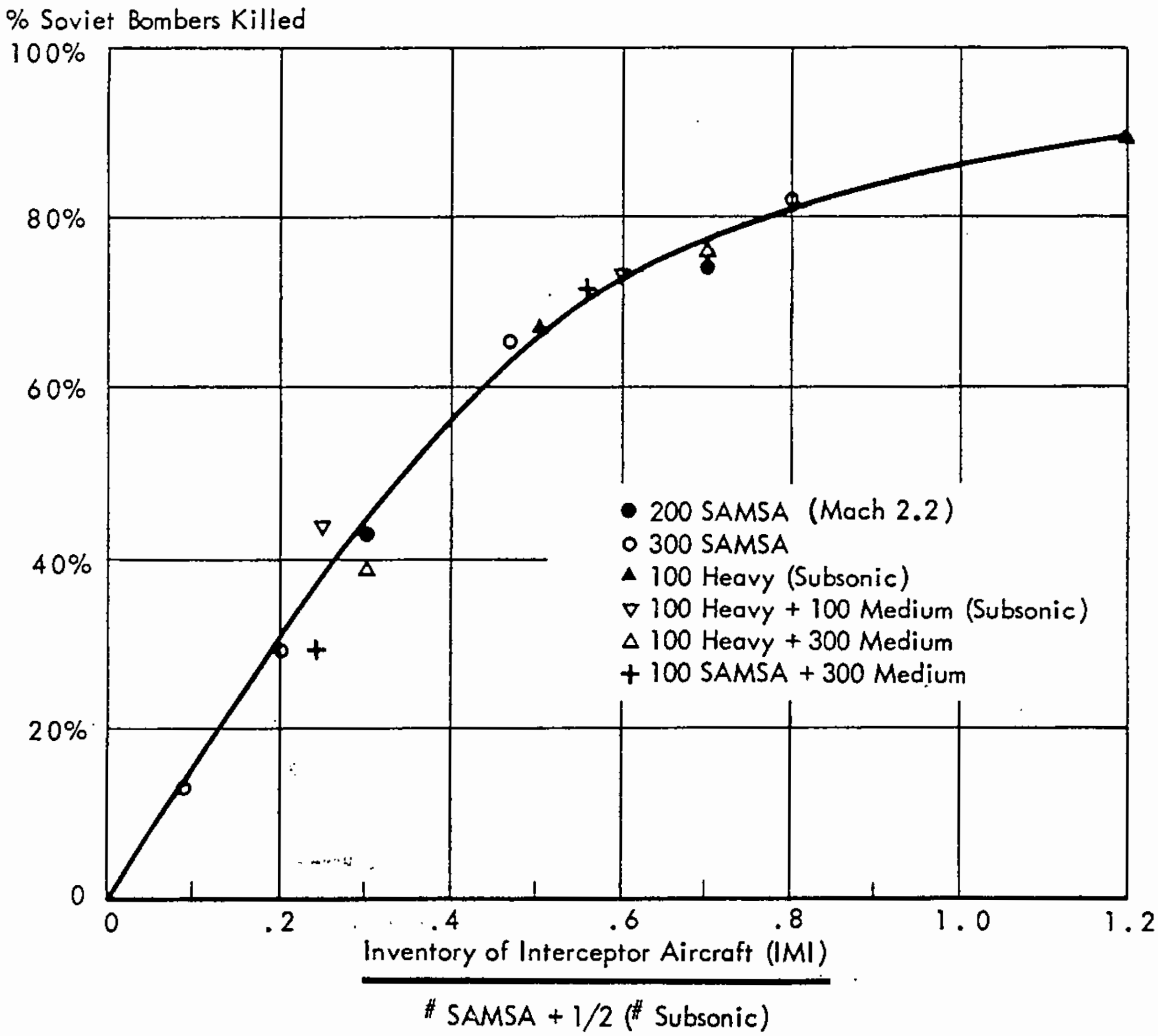

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Figure 13

% SOVIET BOMBERS KILLED BY AREA BOMBER DEFENSE vs. INVENTORY OF INTERCEPTOR AIRCRAFT (IMI)

Purpose

1. To show utility of interceptors used against various Soviet bombers and attack levels.

Basis for Computation

2. Basic Data is from Air Force study and was derived by the Air Force by war game techniques.

3. Defense Suppression consisted of:

   a. 70 Soviet ICBMs launched simultaneously with Soviet bombers, and

   b. 30 long range ASMs carried by Bombers.

4. 50% of interceptors are flushed on tactical warning, recovered, and then recycled from surviving base structure. The other 50% are destroyed by defense suppression.

5. Ground Environment is BUIC (Back-up Interceptor Control) plus approximately 15 AWACS (Airborne Warning and Control System) aircraft on station.

6. Number of Soviet bombers refers to number arriving at U.S. Area Bomber Defense. Number of bombers killed refers to number killed prior to entering U.S. terminal defense area. SAMSA is a Soviet bomber similar in type to a U.S. AMSA (Advanced Manned Strategic Aircraft).

[redacted]

7. Best SAMSA tactic is to fly high at maximum speed, i.e., SAMSA are not subject to simultaneous SAM and interceptor attack. (Note: This would not necessarily be the best tactic if there were a deployment of long range SAMS along northern U.S. border).

Basic Points

8. Percent attrition is determined by ratio of inventory interceptors to arriving bombers. For example, according to the curve, if the U.S. inventory of IMI is one-half the number of Subsonic Soviet bombers arriving at U.S. area air defense, then about 85% of these bombers will be destroyed prior to the time they reach the U.S. terminal defenses. If the number of IMI were one-half the number of SAMSA, then about 65% of the Soviet bombers would be killed prior to reaching terminal defenses.

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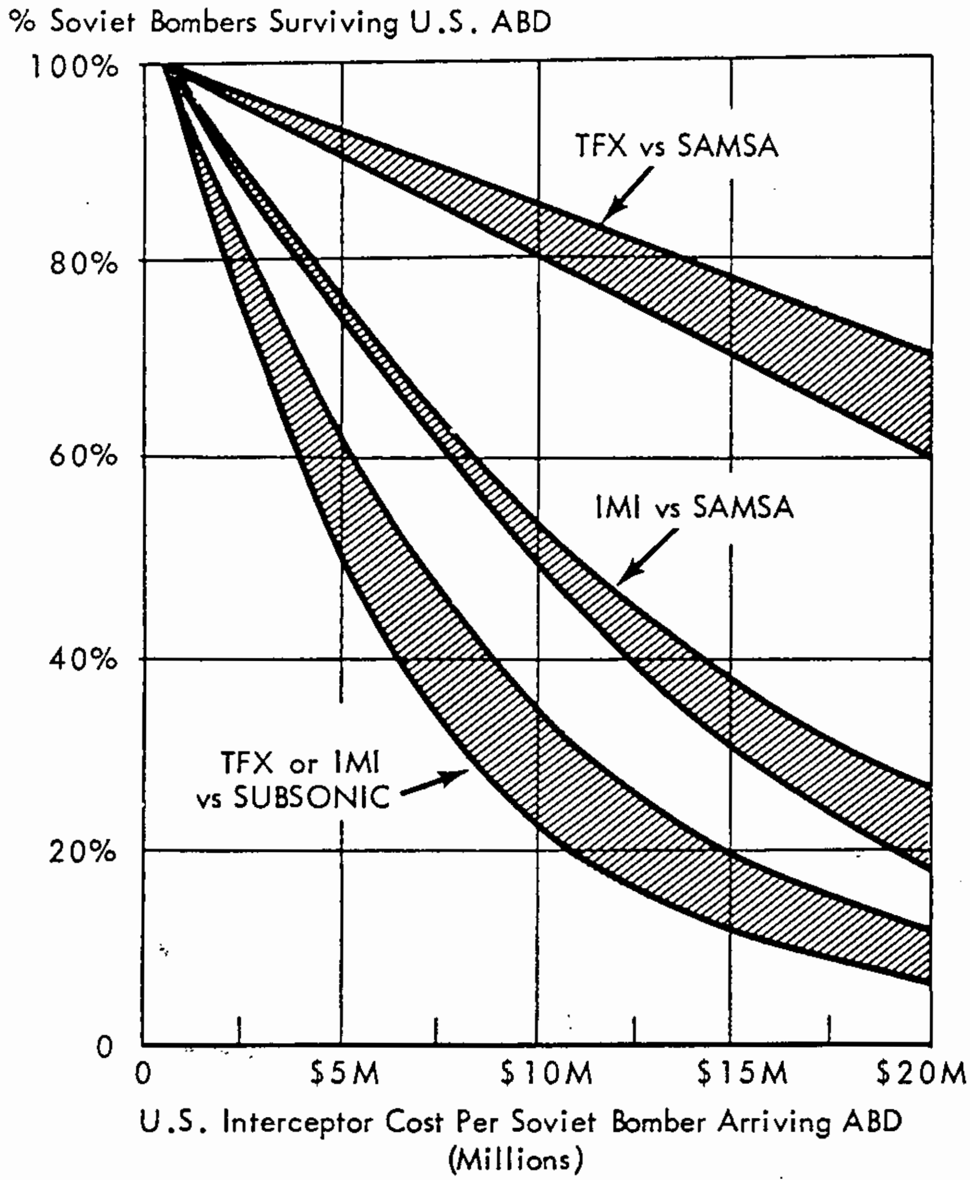
Figure 13a

% Soviet Bombers Surviving U. S. ABD
vs
U. S. Interceptor Cost per Soviet Bomber Arriving U. S. ABD



[redacted]

[redacted]

Figure 13a

% SOVIET BOMBERS SURVIVING vs. COST OF INTERCEPTORS PER SOVIET BOMBER ARRIVING AREA BOMBER DEFENSE

Purpose

1. To show the relative utility of two U.S. interceptors against Soviet subsonic bombers and Soviet AMSA.

Basis for Computation

2. Basic data from Air Force study; see also Figure 13.

3. Attack sizes range from 100 to 300 incoming bombers.

4. The spread reflects the change in average interceptor cost with varying budget level. There is very little spread when percent surviving is plotted versus the ratio:

$$\frac{\text{(number of inventory interceptors)}}{\text{(number of bombers of given type)}}$$

See Figure 13.

Basic Points

5. Both interceptors perform about as well for the same cost against Soviet subsonic threat.

6. Both interceptors do less well against the Soviet SMSA; the IMI, for the same cost, does better than TFX.*

* NOTE: Since the focus of the study is on 197x technology, only IMI vs. SAMSA was carried forward.

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Figure 14

% U.S. Population Surviving
vs
Number of Soviet Bombers Entering TBD Area
for Various TBD Costs

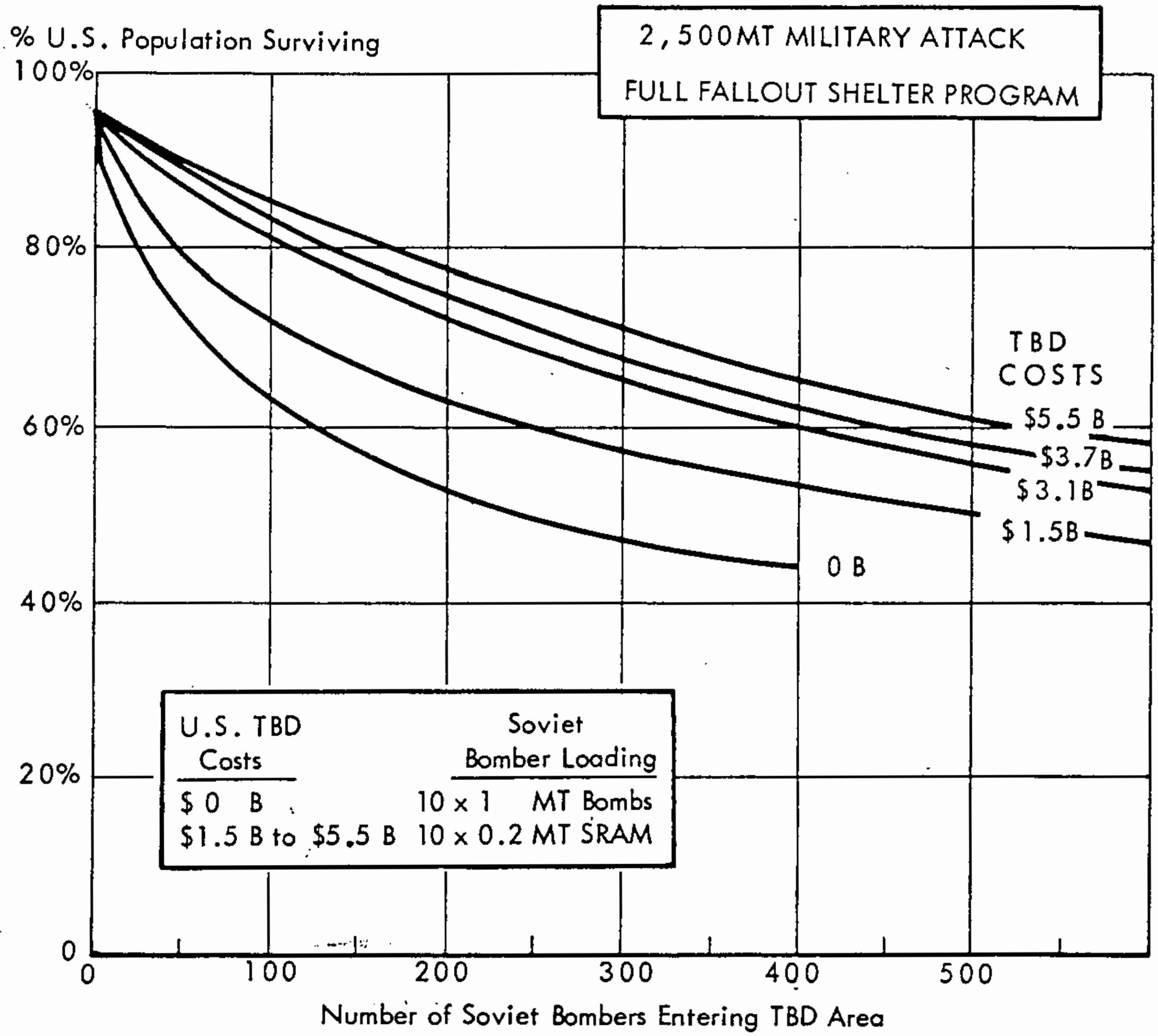

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Figure 14

% U.S. POPULATION SURVIVING vs. NUMBER OF SOVIET BOMBERS ENTERING TERMINAL DEFENSE AREA FOR VARIOUS EXPENDITURES ON TERMINAL BOMBER DEFENSE

Purpose

1. To display utility of pure Terminal Bomber Defense against various bomber threat levels.

Basis for Computation

2. Various levels of bomber attack on population are accompanied by 2500 MT military attack. Full fallout shelter program was used in damage assessment but costs not included in this graph. Basic TBD data is from the Army study.

3. The zero U.S. expenditure level refers to "serial" bombing using 1 MT weapons carried 10 (reliable) per aircraft. Bombers visit as many cities as necessary to target weapons for maximum U.S. fatalities.

4. The 1.5 B expenditure level and higher provides sufficient HAWK/HERCULES units to deny serial bombing for the first 213 U.S. cities. With this level of TBD the assumed best Soviet tactic for operating bombers is to use 300 KT SRAM (Short Range Attack Missiles; Mach 2, low level, 50 mile range) and avoid direct engagement of bombers by TBD. The SRAM are carried 10 (reliable) per aircraft and fired in salvo at each city. The fatalities per salvo are equivalent to fatalities from a single

[redacted]

10 MT weapon. The Army study credited this salvo with the damage potential of a single 10 MT weapon for a 200 KT SRAM yield. It was determined that a 300 KT yield provided a better equivalence to a single 10 MT weapon. With the salvo of ten 300 KT SRAM it takes twice as many bombers to produce the same % U.S. population surviving as when "serial" bombing with 1 MT weapons is permitted.

5. Higher U.S. cost levels refer to the following deployments of AADS-70:

	HAWK/HERCULES		AADS-70		
TBD Cost 1/	Cities	Cost 2/	Cities	# of Batteries	Cost 3/
$1.5 B	1-213	$1.5 B	0	0	0
$3.1 B	29-213	$1.2 B	1-28	62	$1.9 B
$3.7 B	48-213	$1.0 B	1-47	96	$2.7 B
$5.5 B	97-213	$0.8 B	1-96	177	$4.7 B

1/ Total cost of HAWK/HERCULES plus AADS-70, see 2/ and 3/.

2/ Estimated on basis of re-deployment of HAWK from overseas @ $4.25 M/Platoon.

3/ Includes Cost of 1/3 (R&D) + Investment + 5 year annual operating costs.

6. Bombers attack AADS-70 defenses in simultaneous attack with enough salvos of 10 SRAM to saturate defenses. Average number of SRAMs killed per battery is approximately 13.

7. Bombers targeted on first 213 cities to maximize fatalities.

8. As allocations are made to U.S. TBD in Figure 14, it can be

[redacted]

seen that additional Soviet bombers are needed to hold the per-cent U.S. population surviving at a fixed level. Or, put the other way, as the number of bombers arriving increase then the TBD allocation must increase in order to maintain the same percent U.S. population surviving. That is, the additional TBD allocation "negates" the effect of the additional number of bombers arriving. The ratio (added \$ on TBD)/(Bombers negated) (at constant percent surviving) is the marginal cost of TBD. The inverse ratio (Bombers negated)/(added \$ on TBD) is the marginal utility.

Basic Points

9. From the data in Figure 14, the marginal cost of TBD is found to vary strongly with percent surviving but to remain relatively constant as the TBD budget is increased at constant percent surviving. The following values were obtained:

% U.S. Population Surviving	Bombers Negated Per Million $ *	Million $ Per Bomber Negated **
60%	.091	11
70%	.050	20
80%	.026	38
90%	.0096	104

* Marginal utility }
** Marginal cost } At a given "% Surviving", these margins are fairly constant over a wide range of attack sizes.

10. A similar dependence was found for the marginal cost of BMD; see Figure 17. The cost per SRAM negated by AADS-70 is $2 M which is the same as the cost per re-entry object shot down.

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Figure 15

% U.S. Population Surviving vs Cost U.S. FFO/TBD/ABD for Two Levels of Soviet Bomber Attack

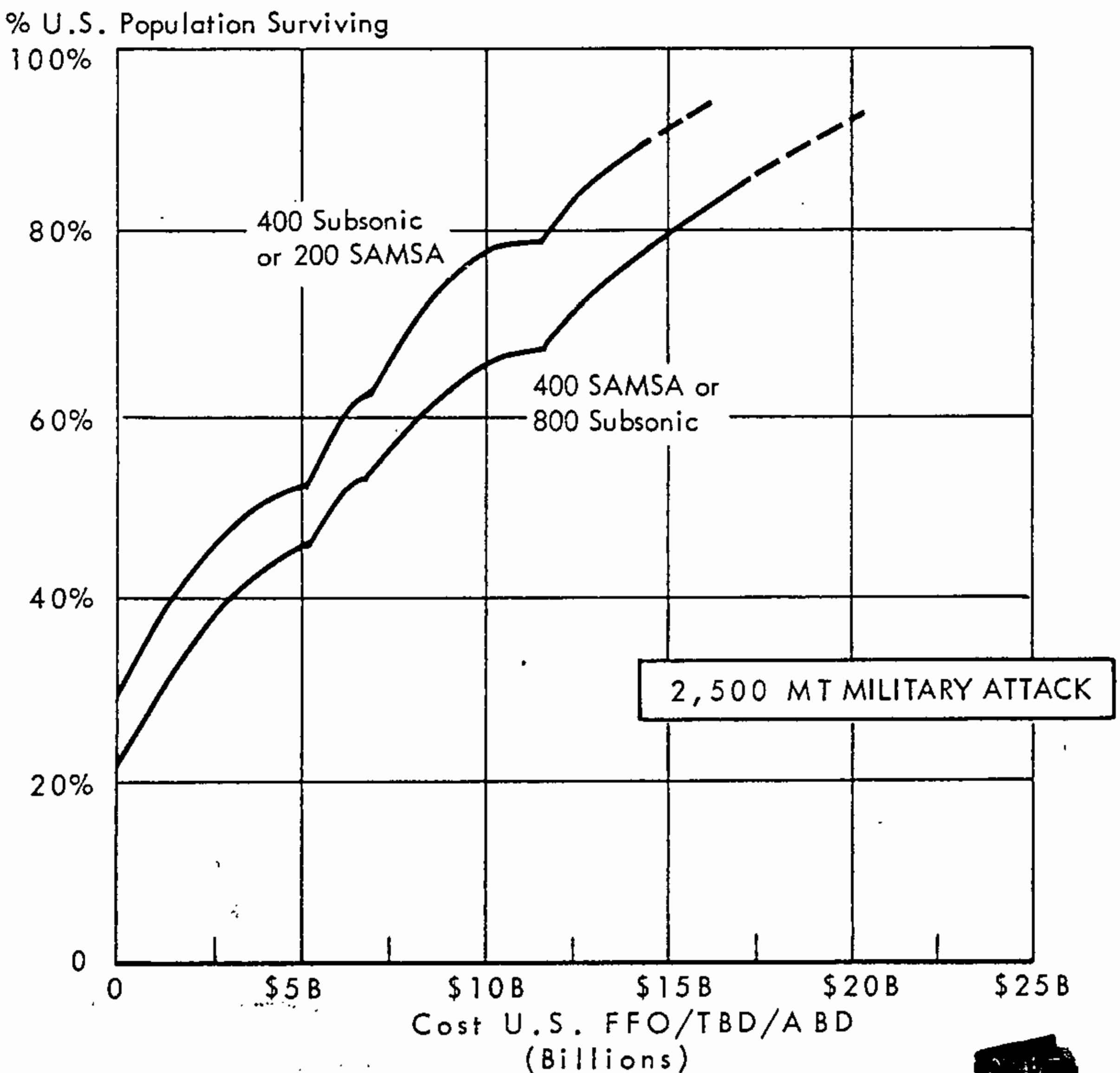

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Figure 15

% U.S. POPULATION SURVIVING vs. U.S. COST IN TBD/ABD FOR TWO LEVELS OF SOVIET BOMBER ATTACK

Purpose

1. To show the utility of a combined Terminal Bomber Defense and Area Bomber Defense against a pure bomber attack on cities, superimposed on a 2500 MT military attack.

Basis for Computation

2. The utility of the four Terminal Bomber Defense deployments outlined in Figure 14 was traded-off with Area Bomber Defense attrition derived from Figure 13 to produce minimum cost combinations at various % U.S. population surviving. (See Figure 15a).

3. Bomber attack on population is accompanied by a 2500 MT military attack. Full fallout shelter program is provided and funded first.

4. The number of bombers refers to number entering Area Bomber Defense. The SAMSA are loaded with ten 1 MT bombs for $0 TBD and ten 0.3 MT SRAM for greater than $1 B on TBD. The subsonic bombers each carry half the SAMSA payload in each case (five 1 MT bombs or five 0.3 MT SRAM). Thus the total payload is the same for either 200 SAMSAs or 400 subsonic bombers (2000 - 1 MT bombs or 2000 SRAM) and the same for 400 SAMSAs or 800 subsonic bombers (4000 - 1 MT bombs or 4000 SRAM).

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Figure 15a

Cost of TBD/ABD
vs
% Allocation to TBD and ABD with Variations in Costs

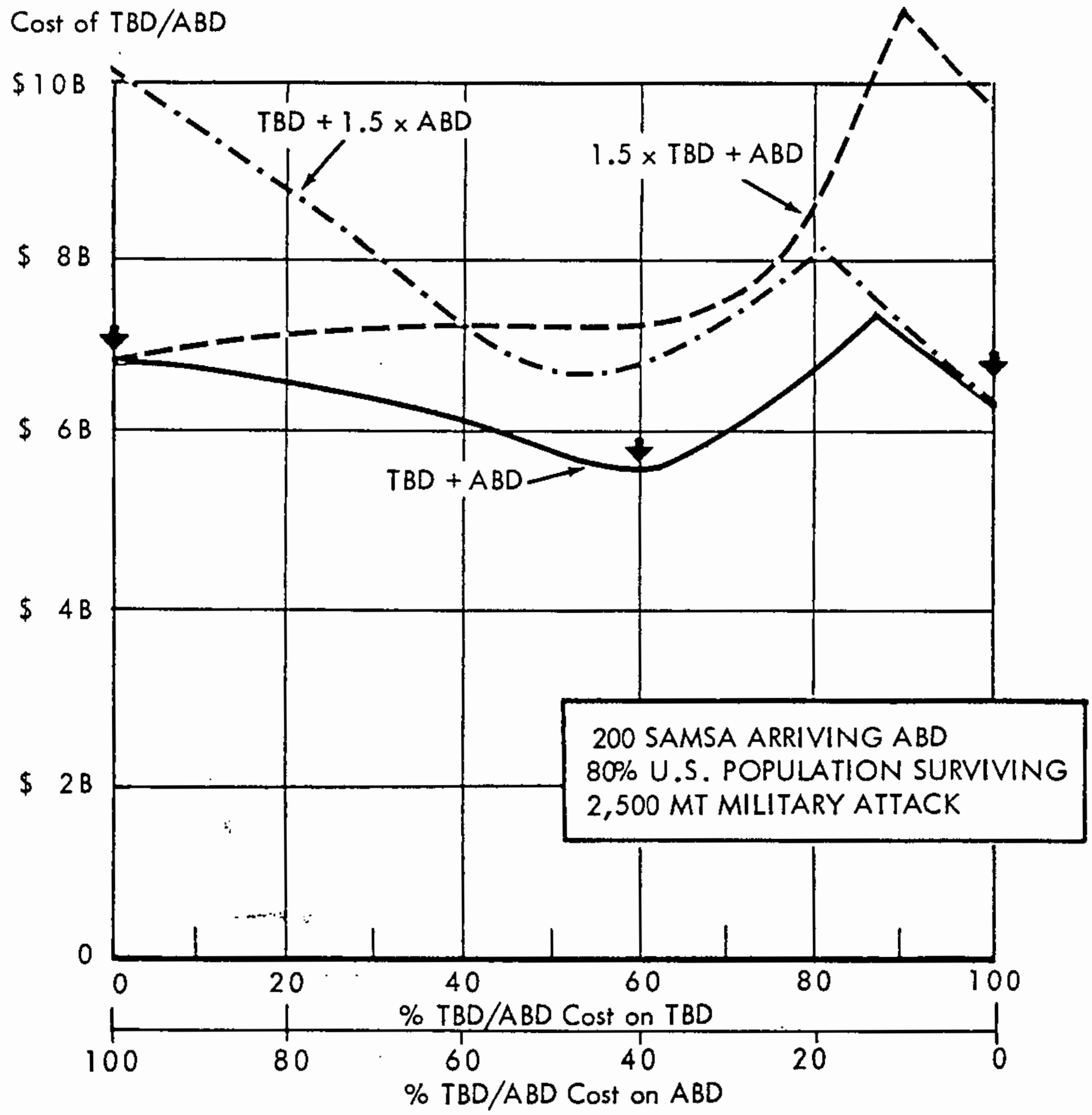

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Figure 15a

COST OF TBD/ABD vs. % ALLOCATED TO TBD AND ABD WITH VARIATIONS IN COSTS

Purpose

1. To show the insensitivity of total TBD/ABD costs for variations in allocations between the two systems.

2. To show the sensitivity of allocations between TBD and ABD on variations in cost (for a given effectiveness) of either system.

Basis for Computation

3. This displays the calculation behind the point at 80% U.S. population surviving for 200 SAMSA (or 400 subsonic bombers) arriving in Figure 15.

4. Since trade-offs are involved in this graph, only amortized costs are displayed.

5. The solid line labeled "TBD and ABD" represents the range of combinations of ABD and TBD using the cost and effectiveness data supplied by the Air Force study and Army study respectively. All points on the solid curve result in 80% U.S. population surviving for 200 SAMSA arriving at the outer edge of the ABD region. The sharp peak on the right side results from the AWACS entry price for ABD. The least cost, or optimum solution, (indicated by the middle arrow) is $5.6 B, allocated as follows:

TBD	59%	\$3.3 B
ABD	41%	\$2.3 B
	100%	\$5.6 B

6. The pure system costs to do the same job (indicated by the left and right arrows) are not very much higher than the optimum:

100% TBD	\$6.3 B
100% ABD	\$6.8 B
Optimum mix	\$5.6 B

This limits the sensitivity of combined cost of ABD/TBD to variations in the allocation between TBD and ABD.

7. In order to study the effect of uncertainties in technical effectiveness and degradation due to defense suppression tactics, two excursions were made. In the first the costs of TBD (for the same effectiveness) were increased 50%. This case is labeled "1.5 x TBD + ABD" in Figure 15a and shows that now the 100% ABD allocation is the optimum allocation. In the second excursion the ABD costs (for the same effectiveness) were increased 50%. This case is labeled "TBD + 1.5 x ABD" in Figure 15a and shows that now the 100% TBD allocation is the optimum allocation.

8. Similar results obtain for most combinations of percent U.S. population surviving and number of aircraft arriving.

9. In the calculations the TBD defenses acted against SRAM missiles -- not the bombers directly as did the ABD. As a consequence, increasing the bomber payload (over the 10 reliable

SRAMs per bomber used) raises the utility of ABD relative to TBD (see Figure 19c for a similar effect in ASW). In the example shown in Figure 15a raising the bomber payload by 50% (15 SRAMs per bomber) results in a 100% ABD allocation; lowering the payload by 50% (5 SRAMs per bomber) results in a 100% TBD allocation.

Basic Points

10. ABD and TBD are closely competitive.

11. Although variations in cost or bomber payload of 50% are sufficient to drastically alter percentage allocations between TBD and ABD, the total cost for a given outcome -- at optimum allocation -- varies less than 20%.

12. This insensitivity in total costs allows the following prescription to be used in defending against mixed Soviet bomber and missile attacks.

   a. Interlock sufficient TBD (AADS-70) at those cities with BMD (NIKE-X) to prevent Soviet bombers from undercutting BMD. This amounts to 20% of BMD cost.

   b. Provide a light cover of HAWK/HERCULES or Area Bomber Defense in the target area sufficient to deny serial bombing.

   c. Add Area Bomber Defense up to the point where the marginal cost to destroy an "equivalent"* KP of bomber payload by ABD is equal to the marginal cost to destroy one KP of missile payload by ASW, SOF or BMD.

* Note: Bomber payload can be equated to missile KP on the basis of the damage that can be inflicted taking into account payload expended on ASM rockets, missile decoys and R/V structure. In particular, sufficient AADS-70 was provided to force Soviet bombers to attack cities not defended by BMD. Against undefended cities Soviet missiles are 10 MT, 4 KP weapons. Against these same cities the SAMSA salvoed their entire reliable payload of ten SRAM with 300 KT apiece. The ten SRAM produce about the same fatalities as the 10 MT missile warhead so that one SAMSA payload is equivalent to 4 KP of missile payload. Alternatively, one can equate bomber payload to missile KP on the basis of the missile KP needed for the same number and yield of multiple R/Vs as SRAMs. In this example, a 300 KT R/V weighs about 0.4 KP so that ten 300 KT R/Vs weigh 4 KP. Thus the same equivalence is reached on both bases.

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Figure 16

Cost per Soviet Missile Killed by Space Boost Phase Intercept (Bambi) vs Duration of Soviet Missile Launchings for various BAMBI Performance Levels

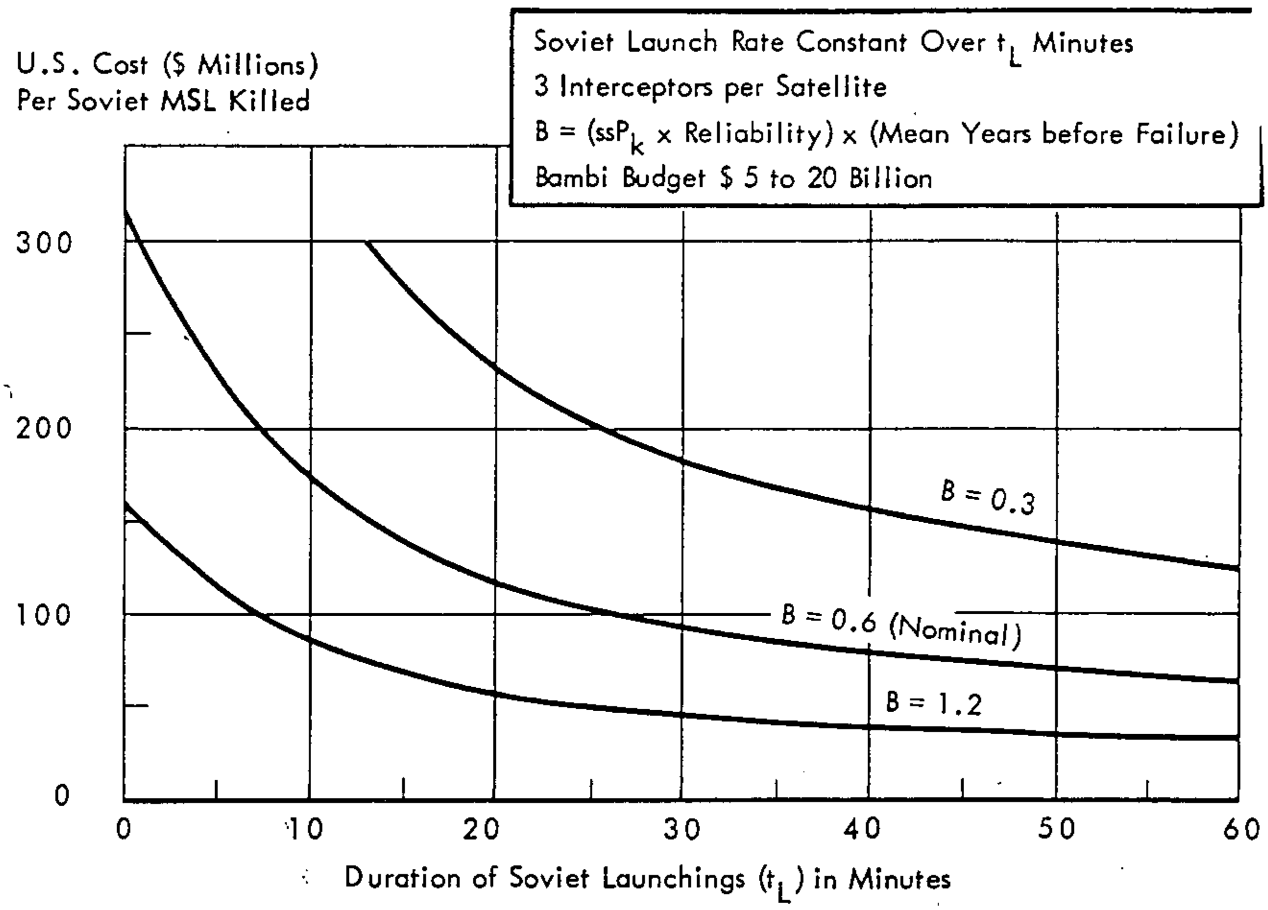

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Figure 16

COST PER SOVIET MISSILE KILLED BY SPACE BASED BOOST PHASE INTERCEPT (BAMBI) vs. DURATION OF SOVIET MISSILE LAUNCHINGS FOR VARIOUS BAMBI PERFORMANCE LEVELS

Purpose

1. To show under what conditions Boost Phase Intercept could contribute to U.S. damage limiting.

Basis for Computation

2. Basic cost and performance data is taken from Air Force study.

3. Soviet launch sites are assumed to be distributed evenly over the launch region which extends from about 40° N. lat. to 50° N. lat. between 30° E. long. and 120° E. long. With an assumed interceptor range of 200 nautical miles it takes 10 satellites on station to cover the entire launch region. To provide these 10 on station on the average requires 270 satellites in orbit.* Five year cost for maintaining 270 satellites in orbit is approximately $5 B. Thus, with 3 interceptors per satellite, there are approximately 30 interceptors within range of Soviet launch sites for each $5 B U.S. cost.

4. The cost data is intended to reflect the nominal value of

$$B = (\text{Interceptors } SSP_k \times \text{Reliability}) \times (\text{mean years before failure})$$

$$= (.6)\ (1) = .6$$

Cost per Soviet missile killed is halved if B doubles and vice versa.

5. Soviet launch rate is uniform (in space) over the launch region and uniform (in time) over t_L minutes. The firing doctrine is one interceptor per detected booster. It is assumed that the offense launches more than enough missiles in time, t_L, to exhaust all the effective satellites that can come over the launch region during time, t_L. This is the optimum offense tactic consistent with a uniform launch rate if, as assumed, BAMBI launches interceptors only at bona fide ICBM boosters.

6. Although each launch site is covered by a different satellite every two minutes, most of the time the newly arriving satellite will have already expended its interceptors at missiles launched from other launch sites. Taking the orbital trace and the launch region geography into account gives a mean replacement time for fresh satellites of about 13 minutes.

7. Typical U.S. cost to negate Soviet missiles (i.e., to offset the deployment of one additional Soviet missile) by SOF and BMD are given below for a Soviet deployment optimized for Soviet second strike (Figure 8) at $12 billion Soviet budget. These can be compared with BPI costs shown on the accompanying graph.

U.S. SOF Budget	U.S. SOF cost to negate one Soviet missile	Soviet optimum KP/missile	U.S. BMD cost to negate one Soviet optimum payload missile at 80% surviving
$ 3.0 B	$27 M	30.0	$600 M
$ 4.6 B	$27 M	9.5	$190 M
$ 7.2 B	$38 M	4.0	$ 80 M
$14.1 B	$38 M	2.0	$ 40 M

For the optimum Soviet deployment described in Figure 8 the U.S. SOF cost to negate one missile depends only upon the U.S. cost per R/V and R/V SSP_k. The change from $27 M to $38 M in the SOF column reflects the increase in cost per U.S. R/V cost at higher U.S. SOF budgets (new buys without sunk costs). For non-optimum Soviet deployments the U.S. SOF cost per missile negated is less than shown. Also given is the U.S. BMD costs to negate a missile at 80% U.S. population surviving (see paragraph 8 of Figure 17). This cost is directly proportional to the payload of a Soviet missile and (slightly) dependent upon the total Soviet kilopounds arriving at BMD.

Basic Points

8. BAMBI utility is sensitive to Soviet launch tactics.

9. Comparison of Figure 16 with the above table shows that BAMBI does not compete favorably with SOF in Soviet second strike.

10. If the Soviets deploy large missiles -- either in response to low U.S. SOF budgets or to maximize Soviet first strike payload for a given budget -- then BAMBI appears to compete with

BMD.* However, large payloads imply few missiles which need only a few gaps in the BAMBI coverage to sneak through.

* NOTE: Because of the technical uncertainties (discrimination of boosters, reliabilities and costs) and the limited circumstances of utility, BAMBI was not used as a damage limiting measure in the remainder of the study.

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Figure 17

Soviet KP Arriving at Terminal Defense vs U. S. Cost for Constant % U. S. Population Surviving

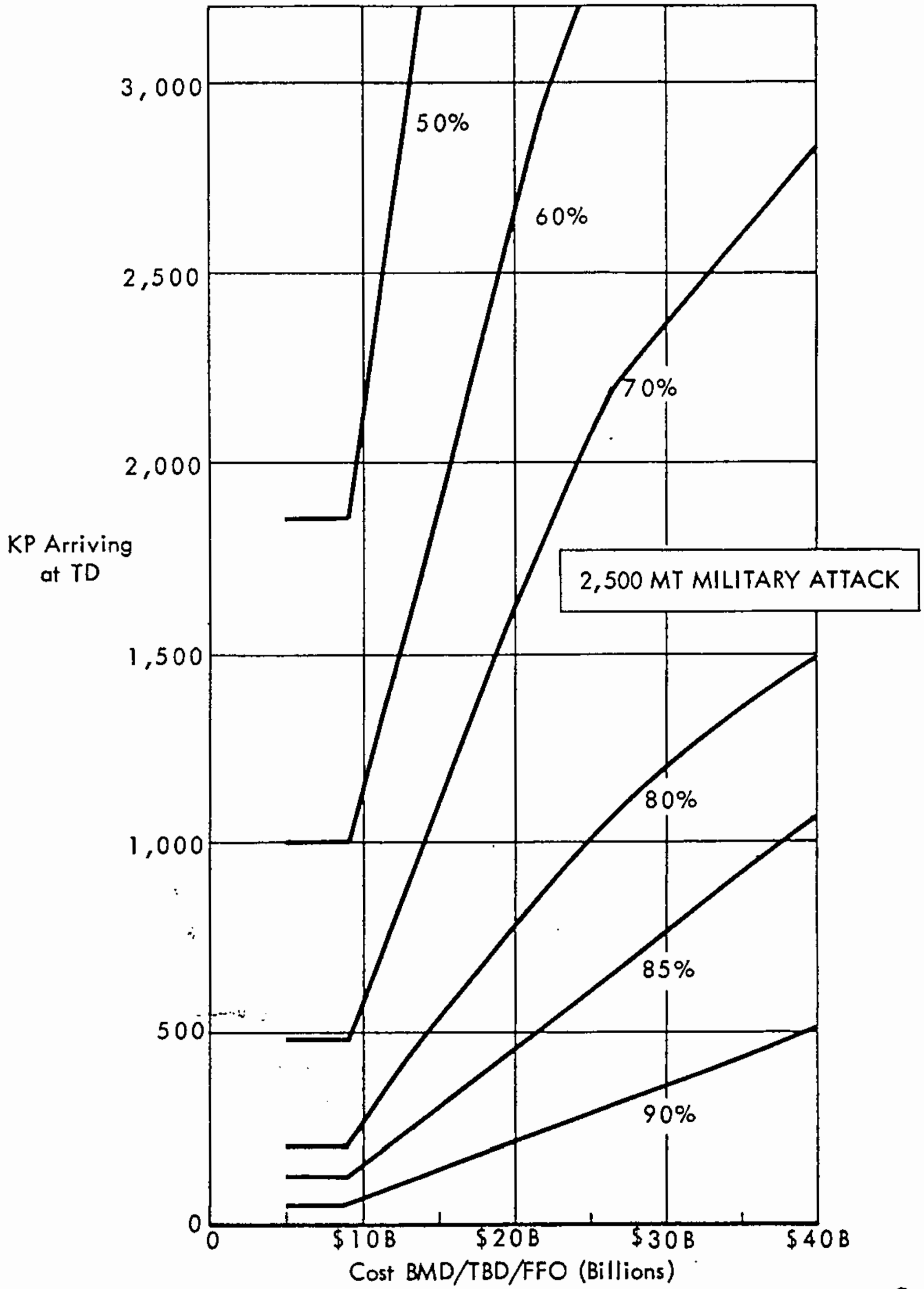

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Figure 17

SOVIET KP ARRIVING AT TERMINAL DEFENSE vs U.S. TD COST FOR CONSTANT % SURVIVING U.S. POPULATION

Purpose

1. To show the effectiveness of active terminal defense (BMD/TBD) added to FFO, in negating the effects of incoming payload.

2. To indicate how this method of analysis, expressing effectiveness in terms of the cost of negating KP, leads to a procedure for integrating the various means of limiting damage. This cost varies strongly with the level of population surviving.

Basis for Computation

3. Computations are based on the Army study.

4. For given expenditures on active Terminal Defense (TD), a graph of % population surviving vs. size of attack can be computed (for example see Figure 14). As allocations are made to TD, the attack size necessary to reduce the surviving population to a given level increases over the zero TD case. In this sense, the defense at that level of survivors can "accommodate" or "negate" the increase in attack size. If the attacker restructures his attack to maximize fatalities, he will minimize the amount the defense can accommodate. This is the basis for the format of the graph shown here. This graph then summarizes the effects of TD expenditures.

5. Included in this chart is the first $5.2 billion spent on the

FFO program; its utility was demonstrated earlier (Figures 3 and 4). The expenditure from \$5.2 to about \$9.2 billion is the "entry price" for BMD/TBD -- R&D and other fixed costs before actual deployment (see Figure 5).

Basic Points

7. The curves show the payload of Soviet missiles "accommodated" or "negated" by TD as a function of TD cost and the level of U.S. population surviving. For example, with a FFO there will be 70% U.S. population surviving for about 500 KP arriving. An additional \$19 B on TD will accommodate an additional 1500 KP or a total of 2000 KP arriving at the terminal areas.

8. The slopes of these curves give the marginal utility of TD -- "KP accommodated" per "dollar expended". The curves are essentially straight lines over a wide range of expenditure, so that the marginal utility is approximately constant. It does, however, vary strongly with the level of population surviving:

% Population Surviving	KP Negated/$ Million*	$ Millions/KP Negated**
50%	.28	3.6
60%	.15	6.7
70%	.11	9.5
80%	.05	20.0
85%	.03	33.0
90%	.015	67.0

* Marginal Utility

** Marginal Cost

9. The above type of analysis on Marginal Cost/KP negated was performed for the utility vs. cost curves for all means of limiting damage. The nature of the optimization calculations shown in subsequent figures is to equate the Marginal Cost -- the marginal cost divided by the marginal KP negated -- over all means of limiting damage. (With various entry-prices in different systems, it is necessary to check that the marginal cost optimum is a true minimum total-cost optimum). This corresponds to minimizing the U.S. cost of resources allocated against a given Soviet threat to achieve a particular level of U.S. population surviving. This constitutes a "balanced defense". An additional dollar allocated, in turn, to any one of the means of limiting damage will bring the same return.

Figure 18

A TABULATION OF THE BASIC CASES OF SOVIET DAMAGE CREATING ALLOCATIONS STUDIED AND ASSOCIATED COST OF OPTIMUM U.S. MEANS OF DAMAGE LIMITING

Note: All cases are for Soviet and U.S. designs for Soviet second strike counter-value. Other cases and excursions are treated in later figures.

$ B Soviet Allocations to				$ B Cost US Lus		Ratio Lus / Csov	
ICBMs	SLBMs	Bombers	Csov Total	70% Surv	85% Surv	70%	85%
6	0	0	6	6.2	10.3	1.03	1.7
12	0	0	12	13.1	25.7	1.09	2.1
6	9	6	21 1/	16.7	32.5	.80	1.5
24	0	0	24	31.2	52.0	1.30	2.2
12	16	0	28	23.6	41.0	.84	1.5
30	0	0	30	45.0	2/	1.52	2/
6	16	9	31	23.2	38.3	.75	1.2
24	0	9	33	36.4	60.0	1.09	1.8
12	16	9	37 1/	31.4	51.6	.85	1.4
24	16	0	40	38.2	65.2	.96	1.6
12	16	16	44	34.8	57.0	.79	1.3
24	16	9	49	47.4	77.0	.97	1.6

1/ Nominal cases carried forward

2/ Data points not available

Figure 18

BASIC CASES OF SOVIET DAMAGE CREATING ALLOCATIONS STUDIED AND ASSOCIATED COST OF OPTIMUM U.S. MEANS OF DAMAGE LIMITING

Purpose

1. To show the range of Soviet threats considered and the effect on the U.S. costs of damage limiting.

Basis for Computation

2. The table illustrates the range of various Soviet threats considered in the intervals indicated below

Soviet Force	Range of Soviet Expenditures
ICBM	$6 B - $30 B
SLBM	$0 B - $16 B
Bombers	$0 B - $16 B

3. Total Soviet damage creating budgets ranged from $6 B to $49 B.

4. No attempt was made to optimize the Soviet expenditures against a given U.S. defense. Clearly, given a U.S. defense, a pure strategy on the part of the Soviets will always be better -- on an expected value basis -- from their point of view. However the case of pure strategy could only be a transient one and not a realistic case. Opposite a pure strategy, the U.S. would re-design its defenses to oppose this strategy so that a mixed strategy would appear better to the Soviets in any event.

5. The tables show, for the basis threats studied, outcomes

derived assuming that both the Soviets and the U.S. designed for Soviet second strike counter-value and that the Soviets did indeed strike second against U.S. population. Other designs, scenarios, and excursions were made using these threats, as will be discussed in later figures.

6. All costs shown in the accompanying table are total investment costs plus five year operating costs.

Basic Points

7. Over a wide range of attacks, the ratio of the cost of U.S. damage limiting to the cost of Soviet damage creating varies between about .75 and 1.5 at 70% U.S. population surviving. This ratio varies from 1.2 to about 2.2 at 85% U.S. population surviving.

8. From the accompanying table a higher proportion of the Soviet expenditures on ICBMs make the above ratio higher. This response to the proportion spent on ICBMs would change. for example, if the Soviet submarine carried more kilopounds payload or were made quieter. When the allocations to Soviet ICBMs and SLBMs are based on amortized costs instead of totall costs, the effectiveness of SLBMs to the Soviets is closer to that of ICBMs.

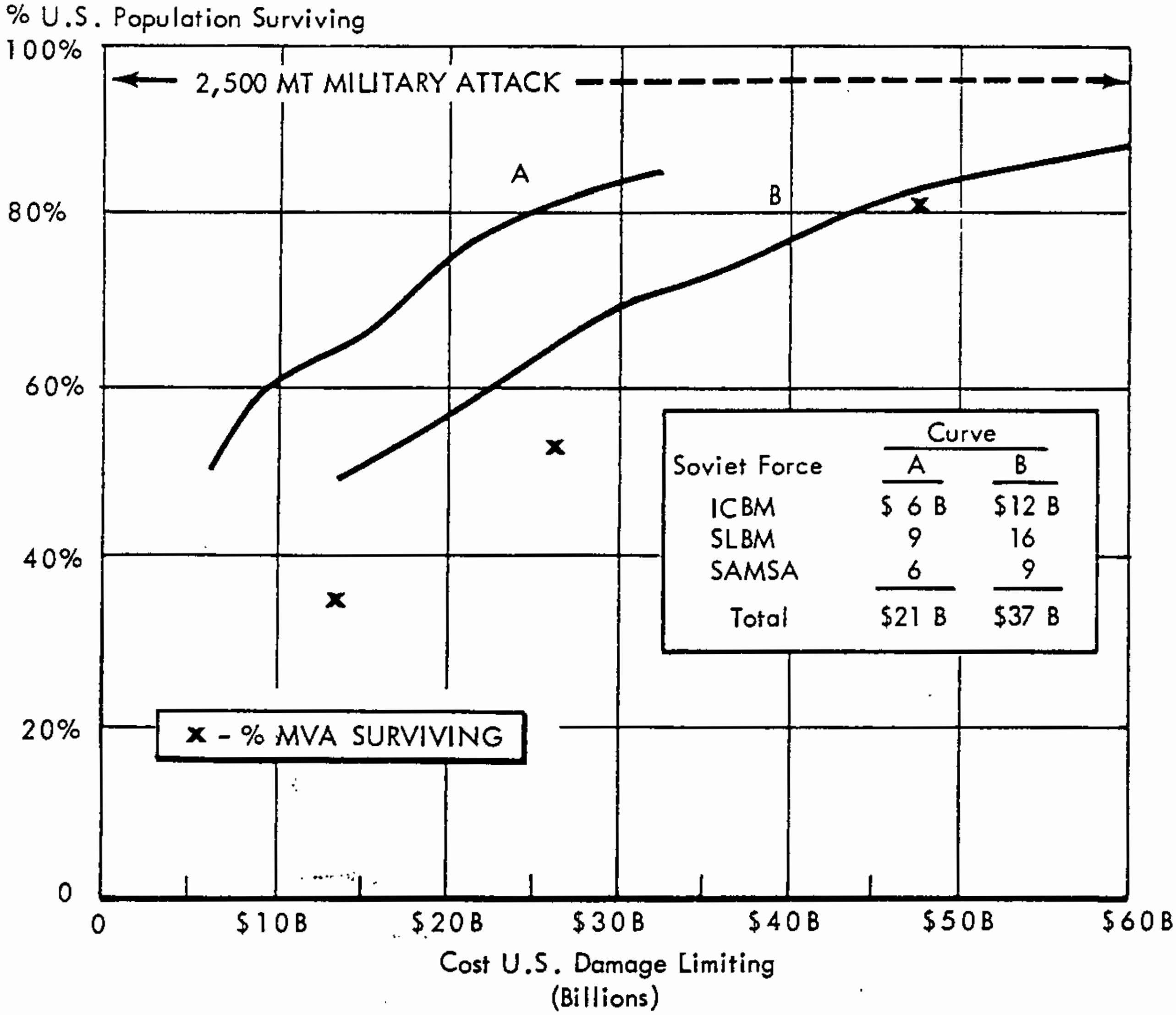
9. A mixed Soviet strategy of $12.0 allocated to ICBMs together with 100 SSBNs in inventory and with 100 bombers arriving at the U.S. area bomber defenses is carried forward as a nominal case. Another example of one-half of these Soviet force levels

is also carried forward. Several excursions in the utility of each of the U.S. damage limiting means were also calculated and appear in later figures.

[redacted]

Figure 18a

% U.S. Population Surviving
vs
Cost U.S. Damage Limiting (Opt)
Soviet 2nd Strike Countervalue



[redacted]

[redacted]

Figure 18a

% U.S. POPULATION SURVIVING vs. U.S. COST DAMAGE LIMITING (OPTIMIZED)

SOVIET SECOND STRIKE COUNTER-VALUE (CV)

Purpose

1. To show, for two Soviet threats, the level of surviving U.S. population vs. U.S. costs when optimum allocations -- within these costs -- are made to all means of limiting damage.

2. This case was chosen to illustrate some (nominal) mixed Soviet forces -- to bring into play all types of damage limiting forces.

Basis for Computation

3. As described in Figure 17, optimum allocations were made at each level of population surviving on the basis of equating marginal costs for all means of limiting damage. The marginal costs were computed from the utility graphs for each type of force with careful attention paid to entry price phenomena.

4. Two Soviet force levels are shown:

Curve A:

$6 billion on ICBMs, optimally deployed to maximize KP surviving (a boundary case -- the best the Soviets could do).

$8.8 B --50 SSBNs in inventory, deployed in a steady-state POLARIS-type operation as described in Figure 12.

$5.7 B --50 SAMSAs arriving at CONUS after 33% attrition by SOF.

[redacted]

Curve B:

The second Soviet threat is just double the inventory force levels in (A) above, maintaining the same relative composition. (Soviet Costs: $12 B on ICBMs, $16.4 B for 100 inventory SSBNs, and $9.2 B for 100 SAMSAs arriving at CONUS).

5. Campaign consists of U.S. counterforce strike: (1) on Soviet ICBMs (100% occupancy); (2) on submarines in port or overhaul (about 20% of submarines); and (3) on Soviet bomber home bases (33% inventory aircraft not on alert). Soviet forces that survive are directed against U.S. and targeted for maximum U.S. population fatalities. By not considering that Soviets can reprogram his force this (conservatively) gives an upper bound on U.S. cost of damage limiting to achieve a given percent U.S. surviving.

6. The calculations are based on fixed Soviet threats and do not attempt to maximize fatalities by changing the <u>mix</u> of forces depending on U.S. allocations. (See Figure 18).

<u>Basic Points</u>

7. Against a given threat, the more money the U.S. allocates to damage limiting, the higher the level of surviving population, and at slowly diminsihing marginal returns. (Utility per dollar expended for a constant threat).

8. As the Soviets increase the threat, the marginal cost (increase in damage limiting cost per unit increase in Soviet threat) for

constant utility) to maintain a given level of surviving population depends on the level surviving. Said another way, the ratio of U.S. costs to limit damage to Soviet costs to create damage is defined by the level of U.S. population surviving. Further this ratio is fairly insensitive to the size of the Soviet attack. (See table below). If the Soviets double their inventory (preserving the same relative mixture) the U.S. damage limiting (DL) costs to maintain the same percent surviving increase by the factor shown below:

% Surviving U.S. Population	Ratio: Cost U.S. / Cost Soviet — Curve A	Curve B	Cost U.S. Curve B / Cost U.S. Curve A
50	.3	.4	2.1
60	.4	.6	2.4
70	.8	.8	1.8
80	1.2	1.2	1.8
85	1.4	1.4	1.6

U.S. costs approximately double for double the Soviet threat. the reason the U.S. costs are less than double at higher levels of surviving population is that doubling the threat and preserving the mixture is not an optimum increase in threat for the Soviets. At higher levels of U.S. expenditures the ratio of KP arriving at terminal defenses per KP in inventory is low for Soviet SAMSA and SSBN and does not increase much if the Soviets double their inventories of these forces. Additional

SSBNs and SAMSAs do not drive up U.S. costs as much as additional ICBMs.

8. The mixed threat shown in Curve B will be used in a number of excursions and sensitivity calculations since it involves all types of damage limiting forces.

<u>Excursions on Curve B</u>

9. If the Soviets had deployed only 4 KP missiles (ICBMs) instead of optimum payloads for these missiles, the overall result is almost the same as Curve B (within $1 B) up to 75% surviving. This is because 4 KP is not far from optimum over this range. At higher levels surviving, it becomes about $5 B cheaper for the U.S. Four KP payloads become further from optimum Soviet deployment and Soviet ICBM KP surviving is approaching negligible proportions.

10. The OIEP ICBM threat for 1975 (High threat estimate in the Air Force study) includes a mixture of soft missiles, soft and hard missiles several to a site, and hardened and dispersed 1.5 KP missiles. If this threat is used in place of the "nominal" ICBM threat of Curve B, the results by coincidence are very close to the same result as Curve B. <u>However</u>, the cost to the Soviets of that ICBM threat in terms of this study is roughly $20 B instead of $12 B for the more or less optimal Soviet deployment of Curve B. This is a measure of how far off optimum (second strike) the Soviets could be in their deployment.

[redacted]

11. The SAMSA bomber forces may be related to equivalent subsonic Bison or Bear bomber forces as follows: (Soviet bomber costs from Air Force study)

	Number Arriving ABD		Cost	
	Curve A	Curve B	Curve A	Curve B
SAMSA	50	100	$5.7 B	$9.2 B
Bear	100	200	$2.0 B	$3.6 B
Bison	100	200	$2.5 B	$4.2 B

12. Curves A and B refer to mixed Soviet forces. The U.S. damage limiting costs would be approximately the same as Curve A for a Soviet pure ICBM force (optimum payload) costing $15 B as opposed to $21 B for the mixed force. Correspondingly, Curve B is approximately the result for a pure ICBM force of $25 B as opposed to $37 B for the mixed force.

13. Further excursions will be treated on separate graphs.

MVA Surviving

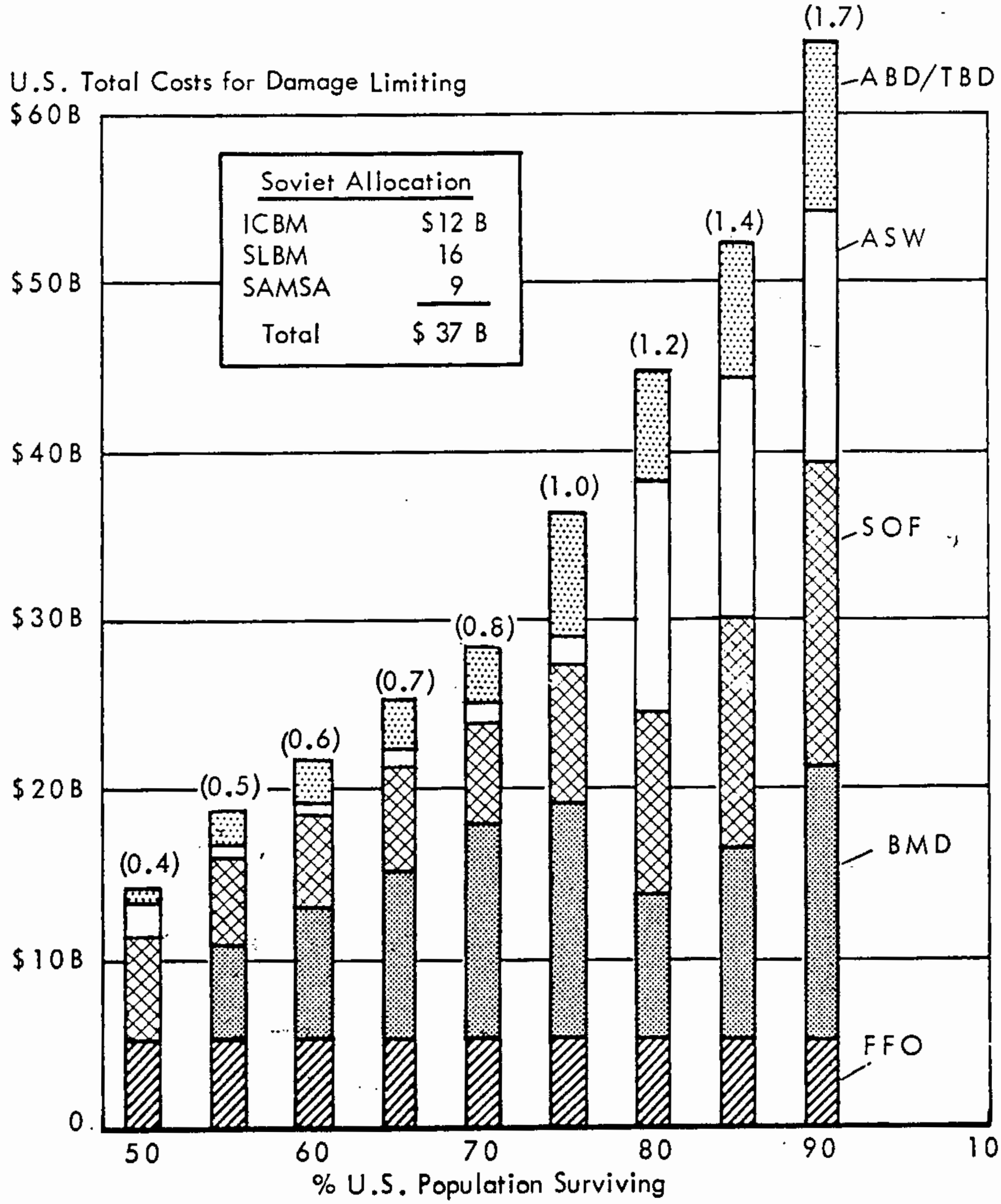
14. The % U.S. MVA surviving a Soviet attack corresponding to Curve B is shown at four points marked with "X's".

[redacted]

[redacted]

Figure 19

Typical Allocation Among
U. S. Damage Limiting Forces
Soviet 2nd Strike Countervalue



NOTE: Numbers in Parentheses are approximate ratio of Cost vs Damage Limiting to Cost Soviet Damage Creating.

[redacted]

Figure 19

TYPICAL ALLOCATION AMONG U.S. DAMAGE LIMITING FORCES

Purpose

1. To exhibit the varying allocation of resources among U.S. damage limiting forces at increasing percent U.S. population surviving.

Basis for Computation

2. The allocations refer to Curve B of Figure 18 -- the U.S. designs for Soviet second strike Counter-Value. No priority is associated with the order of individual allocations on the bar graph. The allocations are not sharply defined, as will be discussed below and in subsequent Figures. The allocation at each % U.S. population surviving is the end point of a particular force build-up. It is entirely inappropriate and misleading to associate any time-order of the allocation with % surviving.

3. The U.S. damage limiting forces are grouped as follows:

FFO - Full Fallout Shelter program (see Figure 3)

BMD - Ballistic Missile Defense (see Figure 5)

SOF - Strategic Offensive Forces (see Figures 8, 9 and 10)

ASW - Anti-Submarine Warfare forces against Soviet SLBM (see Figure 12)

ABD/TBD - Area Bomber Defense including interceptors and AWACS aircraft combined with Terminal Bomber Defense (see Figure 13 and 13a)

4. Soviet Forces are the <u>same</u> as Curve B of Figure 18a):

   $12 B - ICBM in optimum payload deployment (see Figure 8)

   $16 B - SLBM to provide 100 inventory submarines (12 KP missile payload per boat) deployed in a steady-state POLARIS-type operation

   $9 B - SAMSA to provide 100 aircraft arriving at Area Bomber Defense

5. The campaign consists of U.S. counterforce strike: (1) on Soviet ICBMs (100% occupancy); (2) on submarines in port or overhaul (about 20% of submarines); and (3) on bomber home bases (33% inventory aircraft not on alert). Soviet forces that survive are directed against U.S. and targeted for maximum U.S. population fatalities.

<u>Basic Points</u>

6. FFO shelter is always bought -- $5.2 B.

7. BMD receives between $6 and $16 B except at 50% U.S. population surviving where the BMD fixed cost buy-in ($2.4 B) forces a total cost optimum (see Figure 17, paragraph 3) that has a zero BMD allocation. SOF and ASW allocations are raised to compensate. The strict marginal cost solution has $6 B in BMD and results in a total cost that is $2 B higher than shown in Figure 19 for 50% surviving.

8. SOF receives a steadily increasing (with % surviving) allocation except for a decrease between the 50% surviving point and the 60% point (see paragraph 7 above). The SOF allocation is

always between 20% and 30% of the total.

9. ASW has two general levels of allocation. A low level (about \$2.0 B) allocation up to 75% U.S. population surviving and a high level (about \$15 B) above 75% surviving. This large shift occurs when ASW forces beyond existing ASW forces (see Figure 12) become competitive with BMD (whose marginal costs rise steadily with percent U.S. population surviving -- see Figure 17). As can be seen in Figure 19, the increased ASW allocation comes at the expense of BMD. The percent U.S. surviving at which the ASW shift (of allocation from low to high) occurs depends, sensitively, upon the missile payload of each submarine; see Figure 19c.

10. The combined budget to negate bombers (ABD/TBD) is about 20% of the combined budget to negate missiles (SOF/ASW/BMD) at most % surviving.

11. The internal allocations are more sensitive to changes in force effectiveness and cost than is the total cost. If the large ASW entry or ABD entry were arbitrarily shifted up or down by 10% (in percent population surviving), the total costs would be increased less than 5%.

12. Figures 19 a and b will show that these specific allocations are not sharply unique -- there is a range of very nearly optimum solutions around the specific allocations shown here.

[redacted]

Figure 19a

Cost SOF
vs
Cost ASW for Constant ICBM + SLBM KP Surviving

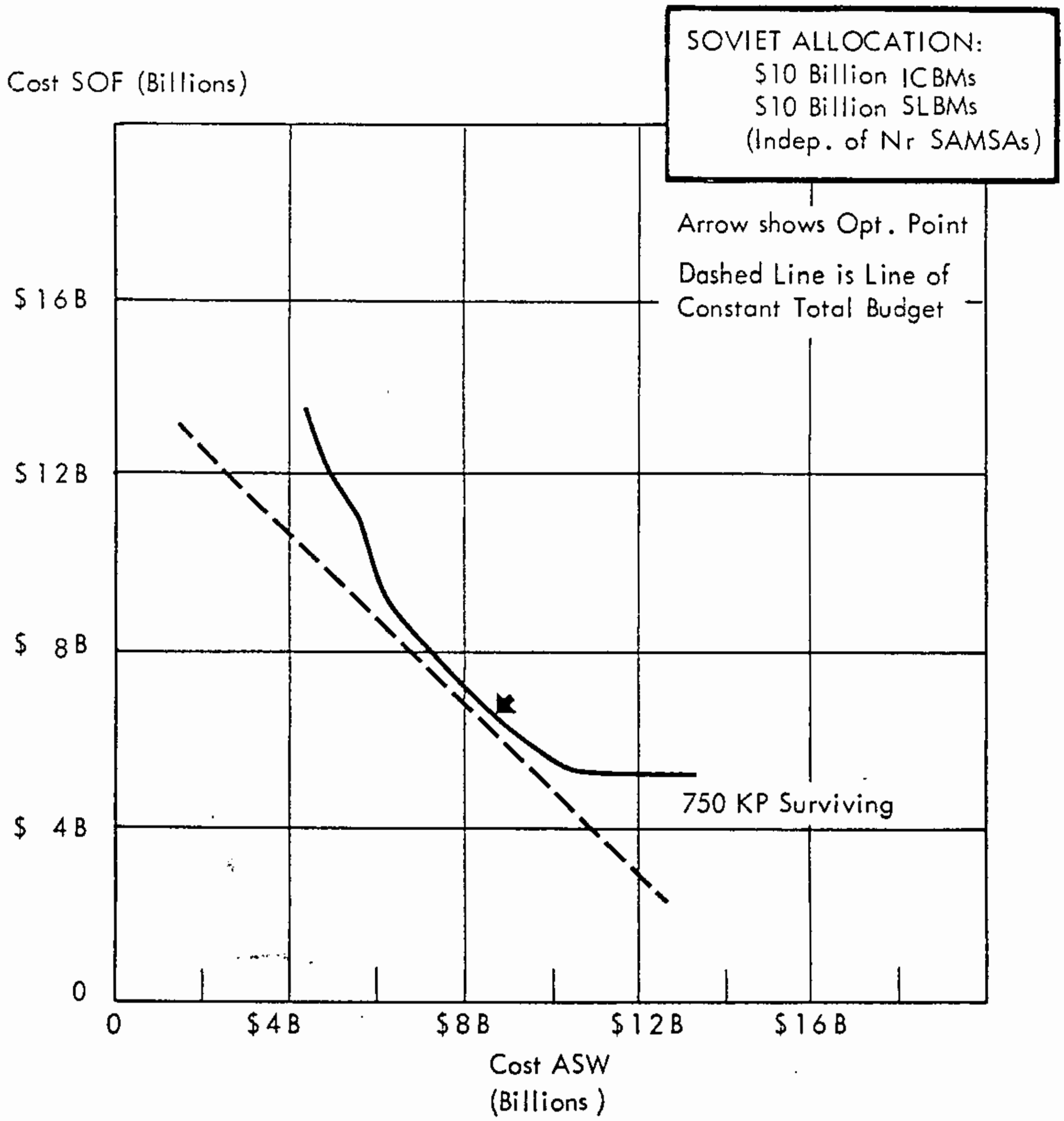


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Figure 19a

COST OF SOF vs. COST ASW FOR CONSTANT TOTAL KP SURVIVING

Purpose

1. To show an example of the broad optima found in sub-optimizing between types of forces. (This is a particularly broad one).

Basis for Computation

2. Computations are based on utility curves for the various systems addressed.

3. The nominal case, Curve B, Figure 18a, is used here.

4. Amortized costs, used in making trade-offs, are shown here. The dashed line displays all combinations of ASW and SOF budgets that add up to $15 B.

Basic Points

5. For a combined U.S. cost of $15.0 billion on ASW and SOF, 750 reliable Soviet (ICBM plus SLBM) KP are surviving and arrive over CONUS. This is for a total Soviet cost of $20 billion. One can have the same utility for very nearly the same combined U.S. budget by allocating $6.4 B to ASW and $8.8 B to SOF (a total of $15.2 B) or $10 B to ASW and $5.4 B to SOF (a total of $15.4 B) or any combination in between.

6. This indicates that the allocations within a given combined budget are only mathematically unique -- there is often a broad region of near optimum choices. The specific allocations used in the study (actual minimum point of total cost) are then

[redacted]

representations of the "ball-park" of optimum allocations. Further criteria for specific allocations can be brought to bear: (a) judgment, (b) hedges against uncertainty, (c) hedges against off-design cases, (d) general purpose vs. single purpose forces, and so on.

[redacted]

B

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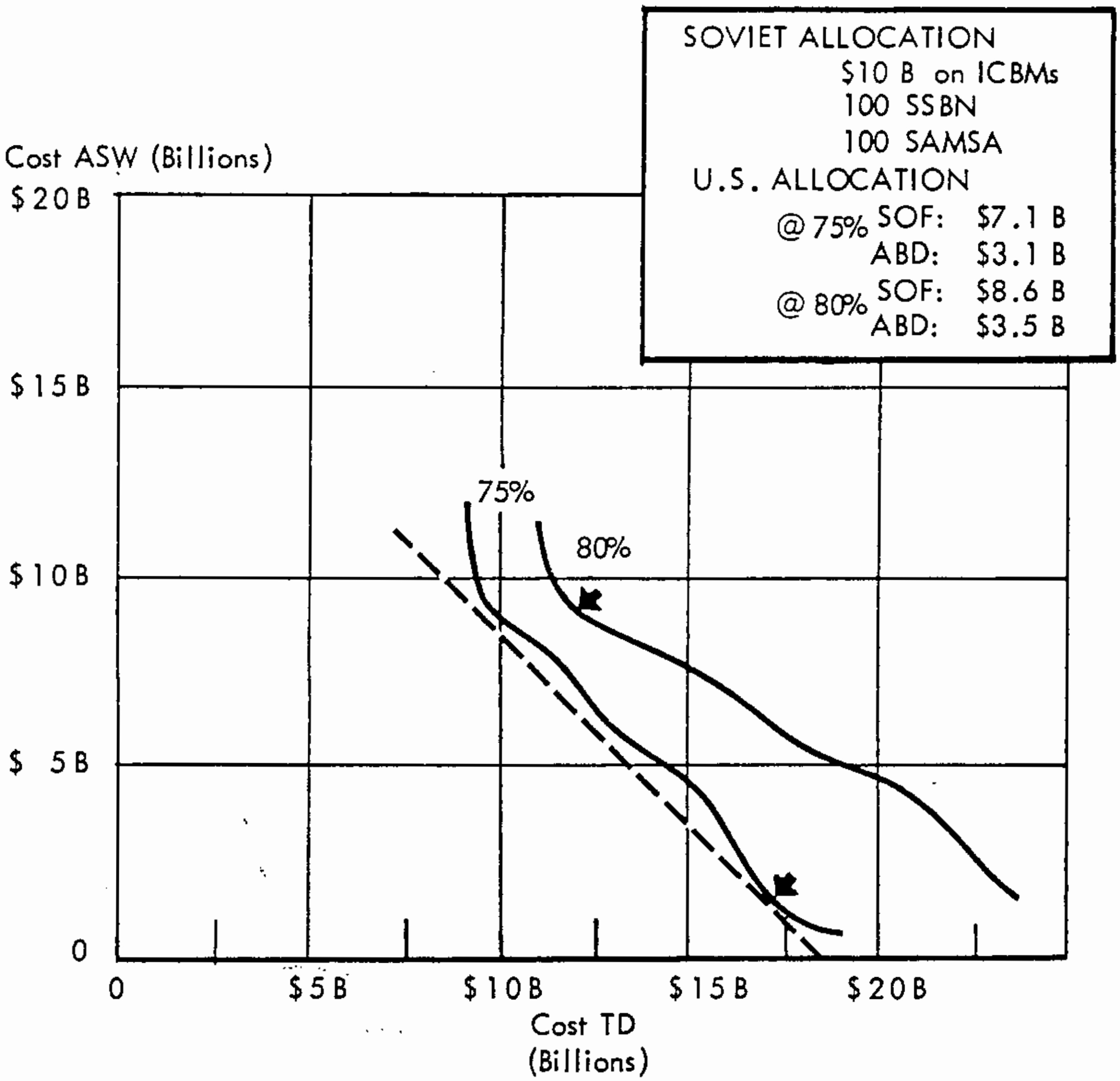
[redacted]

Figure 19b

Cost ASW
vs
Cost TD for 75% U.S. Population Surviving
Soviet Second Strike Counter-Value



[redacted]

[redacted]

Figure 19b

COST ASW vs. COST TD for CONSTANT % U.S. POPULATION SURVIVING

Purpose

1. Same as Figure 19a but for ASW vs. TD (BMD/TBD/FFO).

Basis for Computation

2. Conditions same as Figure 19a.

3. Amortized costs, used in making trade-off's are shown here.

Basic Points

4. This trade-off reflects more clearly the entry price phenomena of ASW (various "buy-ins," like SOSUS). There are essentially three regions on the 75% surviving curve that are very close to minimum combined costs that represent $1.5, $6.5 and $9 billion allocations to ASW respectively. Between these points the total costs increase somewhat representing entry prices of new forces needed to get the higher ASW utility at the next (near) minimum. At 80% surviving, even with the entry prices, ASW can accommodate, or negate, the SLBM KP more economically than can TD up to about $9 B allocation to ASW.

[redacted]

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Figure 19c

$ U.S. Optimally Allocates to ASW
vs
Number KP per Soviet SSBN for
Various Constant % U.S. Population Surviving

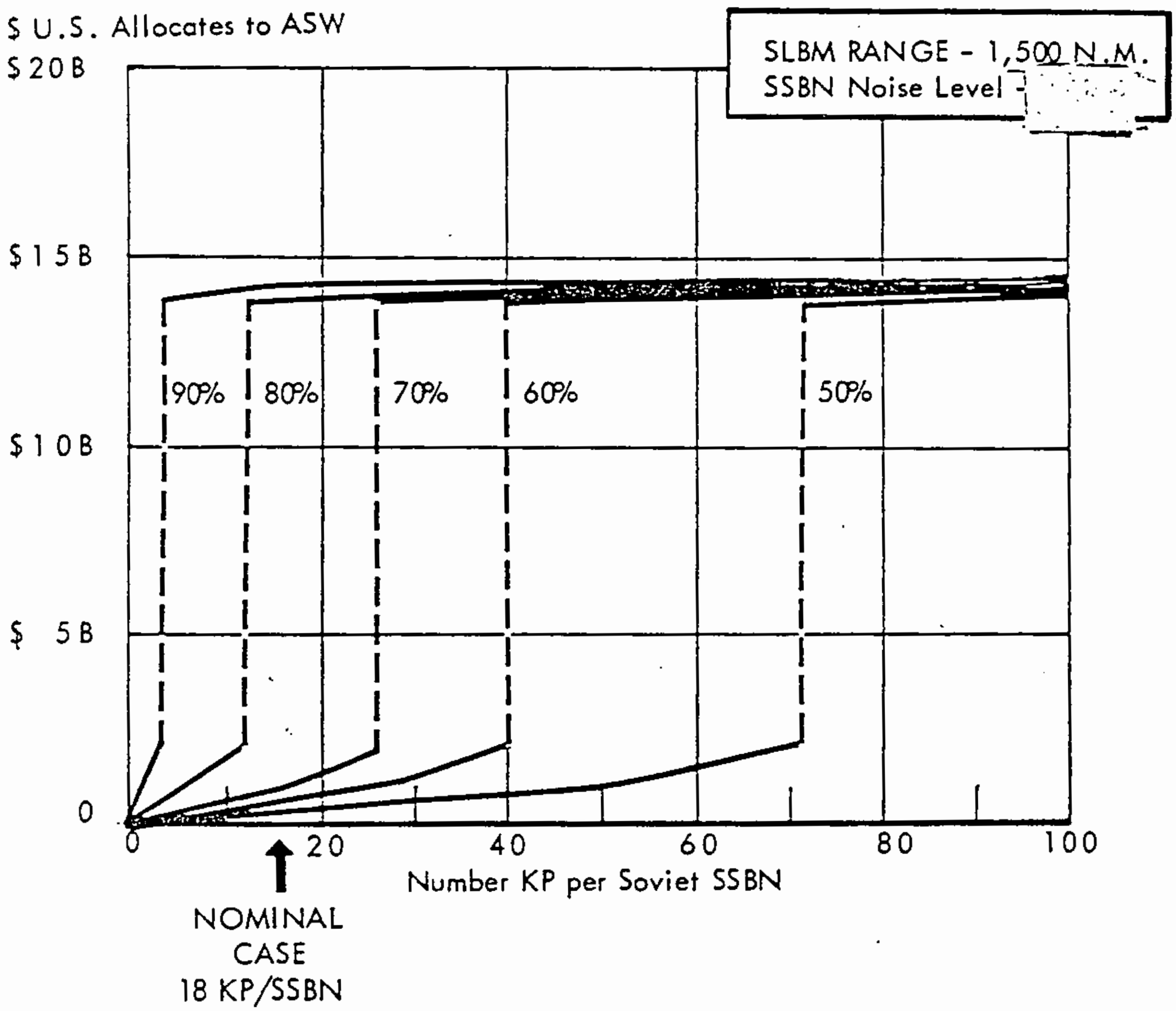

Figure 19c

$ U.S. OPTIMALLY ALLOCATES TO ASW vs. NUMBER KP PER SOVIET SSBN for VARIOUS CONSTANT % U.S. POPULATION SURVIVING

Purpose

1. The purpose of this graph is to display the sensitivity of allocations to ASW on the more important parameters.

Basis for Computations

2. The utility of ASW does not show continuously diminishing marginal returns because of the complex entry prices as explained in Figure 12.

3. In the computations for this figure, the number of KP per Soviet SSBN was varied continuously and the optimum allocation recomputed at the marginal cost corresponding to each percent U.S. population surviving.

Basic Points

4. The allocation to ASW is very sensitive to Soviet missile range, Soviet SSBN level of quieting and KP per SSBN. The nominal ASW case was computed for a 1500 n.m. range Soviet missile, [redacted] and 18 KP per SSBN. Below are tabulated numerical factors by which the costs of ASW in the nominal case can be multiplied to obtain approximate ASW costs in other cases. These factors were computed

from the Navy study and are considered "ballpark" only.

(5)

% Soviet SSBN Destroyed	New Missile Range (n.m.)/ 2000	1500	2000
40%	1.25	2.00	2.75
60%	1.25	3.50	4.50
80%	1.25	4.00	5.50

5. Using the above factors, the nominal case is applicable to steady-state deployment of the following Soviet SLBM/SSBN designs at 80% Soviet SSBN killed:

	Design I*	Design II	Design III	Design IV
Missile Range	1500	2000	1500	2000
KP/SSBN	18	23	70	97

*nominal

Note: Allocations to various means of limiting damage are made at the marginal cost for negating a KP; doubling the number of KP/SSBN while at the same time doubling the cost because of an increased threat (range or leaves the marginal cost unchanged.

6. The discontinuities in the graph occur at \$2.0 B because, as can be seen in the upper curve of Figure 12, the marginal cost per KP negated (about \$15 M/KP at \$2.0 B) is always higher and does not compete with terminal defense until an ASW expenditure of \$14.2 B is reached.

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[redacted]

Figure 20

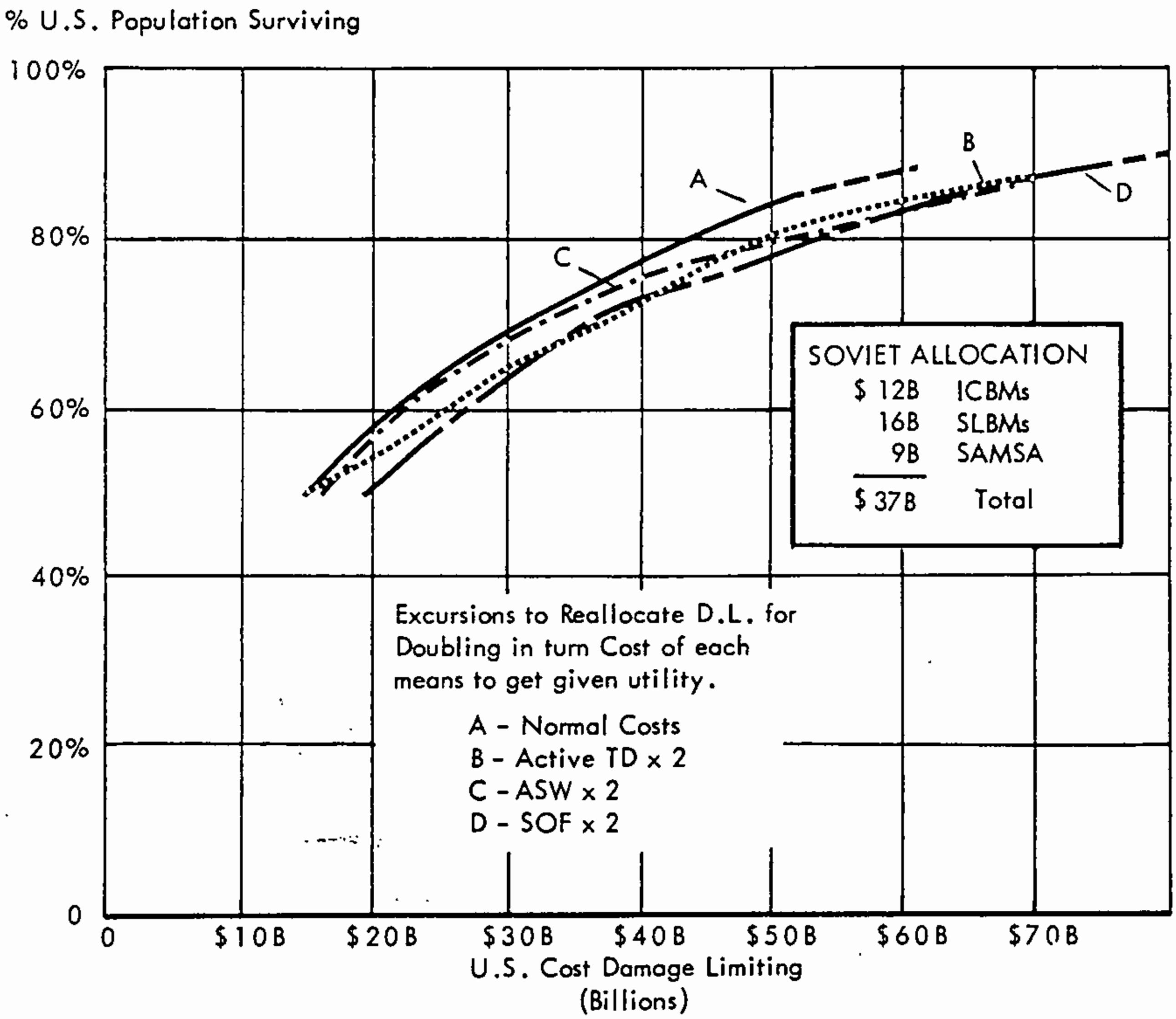
% U.S. Population Surviving

vs

Cost U.S. Damage Limiting

Soviet Second Strike CV

EXCURSION



[redacted]

Figure 20

% U.S. POPULATION SURVIVING vs. U.S. COST DAMAGE LIMITING

SOVIET SECOND STRIKE COUNTER-VALUE

EXCURSION

Purpose

1. To show sensitivity of a nominal case (Curve B, Figure 18a) to doubling the cost to get a given utility for each type of force, in turn.

Basis for Computation

2. Same as Figure 18a, except re-allocation of forces based on doubling costs of each type of force, in turn.

CURVE	DOUBLES COST OF:
A	None (Nominal Case, "Normal" Costs)
B	BMD/TBD
C	ASW
D	SOF

ABD excursion is not included as it showed the smallest deviation. ABD and TBD excursions have been treated separately in Figure 15a.

Basic Points

3. The spread over all deviations lowers the percent surviving by as much as 6%. For maintaining a given percent surviving the costs to achieve a given level increases the cost by up to 25% in the worst cases.

[redacted]

4. The most sensitive change is doubling the cost of SOF. Doubling the costs of BMD/TBD results in almost the same increase in cost for a given percent surviving as is caused by doubling the cost of SOF. The ASW effect is fairly insensitive except above 75% surviving where larger ASW expenditures are made.
5. With many types of forces operating, an increase in cost (to get a given utility) of one type of force can in most cases be accommodated (at smaller changes in total cost) by increasing the allocations to the other types of forces.
6. Significant trends in allocations in this excursion:
   a. Doubling the cost of BMD/TBD to achieve a given utility results in its not mixing with other forces (that is, zero allocation to BMD/TBD) until the 70% surviving level instead of 55% as in the base case.
   b. Doubling the cost of ASW forces results in almost the same allocation of money (but fewer forces) as in the base case until one reaches 85% surviving when one "pays the price" and buys almost as many forces as before.
   c. Doubling the SOF costs results in allocating about 50% more money to SOF forces (but about 75% as many forces as in the base case).

[redacted]

B
L
A
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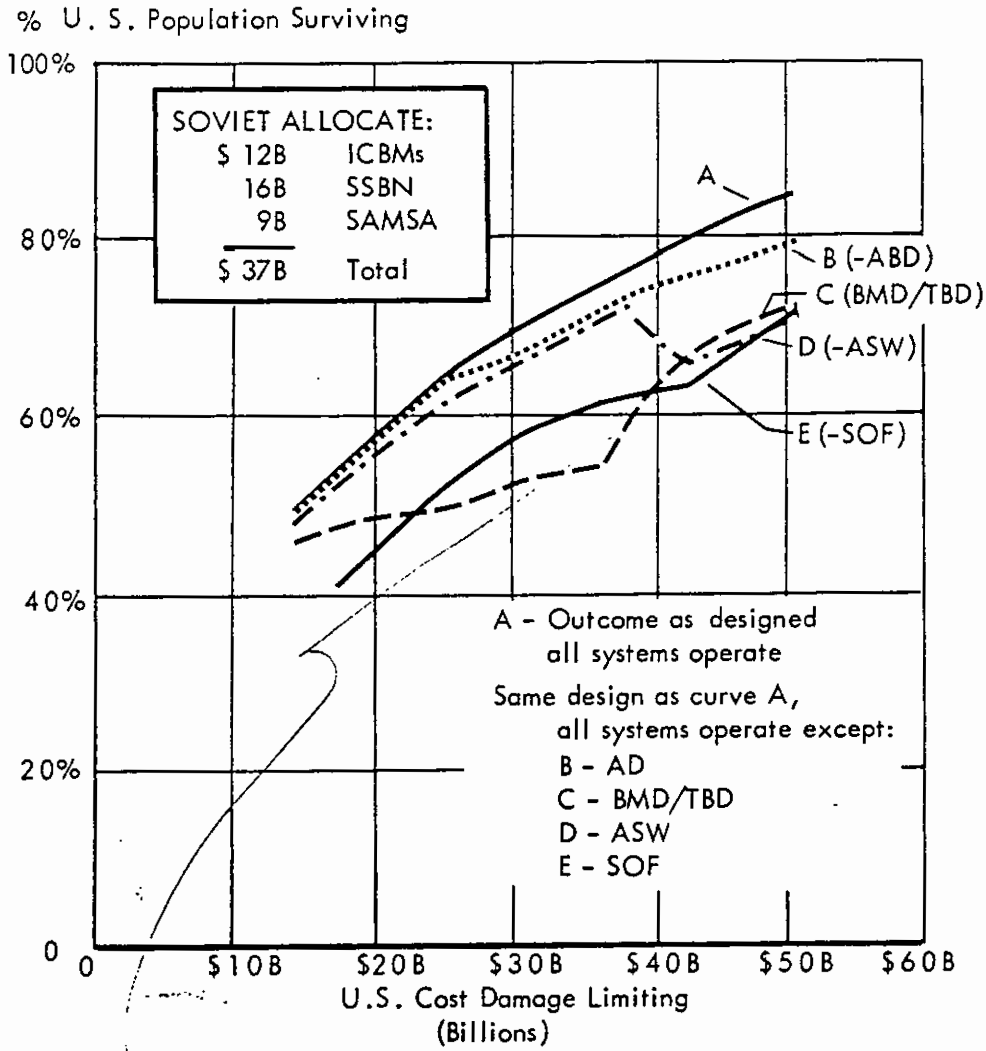
K

[redacted]

Figure 21

% U.S. Population Surviving
vs
Cost U.S. Damage Limiting for Various Forces not Operating Soviet Second Strike Counter-Value

EXCURSION



[redacted]

Figure 21

% U.S. POPULATION SURVIVING vs. U.S. COST DAMAGE LIMITING SOVIET SECOND STRIKE COUNTER-VALUE EXCURSION

Purpose

1. To show sensitivity of results if optimum allocations are made (in the "nominal case," Curve B, Figure 18a) but each type of damage limiting force, in turn, does not get to operate.

Basis for Computation

2. Optimum allocations are those of Figure 19.

3.

CURVE	FORCE NOT OPERATING
A	None (All operate--nominal case)
B	ABD
C	BMD/TBD
D	ASW
E	SOF

4. Case E, SOF not operating, also corresponds to Soviet's first strike counter-value, if the Soviets use their entire inventory force in a counter-value attack and the U.S. designs for Soviet second strike counter-value.

[redacted]

Basic Points

5. If area bomber defense (ABD) does not operate, the level of population surviving drops as much as 5% at high U.S. budget levels. TBD partially offsets the effect of the 100 bombers which get through the area defense in this case.

6. If ASW does not operate, the loss in survivors is small (up to 4%) until U.S. budgets reach $36 B where the allocation shifts to large ASW budgets (Figure 19). In that region the loss is about 15% of the population.

7. If active terminal defense (BMD/TBD) does not operate, the losses increase from about 4% to 20% up to $36 B U.S. budgets and decrease to about 15% thereafter. This is again the result of the ASW-BMD/TBD allocation shift at higher budgets.

8. If SOF does not operate (as in Soviet first strike counter-value), the U.S. population surviving is reduced by about 10% at lower budget levels and about 15% at higher budgets. (Soviet first strike counter-value will be treated in more detail on the following graph.)

9. As shown in Figure 19a and b, the region around an optimum allocation contains a spectrum of near optimum cases. The allocations can thus be altered (for very small changes in total costs) to hedge against uncertainties--such as the limiting cases shown in this chart--and reduce off-design losses.

[redacted]

B

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[redacted]

Figure 22

% U.S. Population Surviving vs Cost of U.S. Damage Limiting for Various Soviet - U.S. Designs and Scenarios

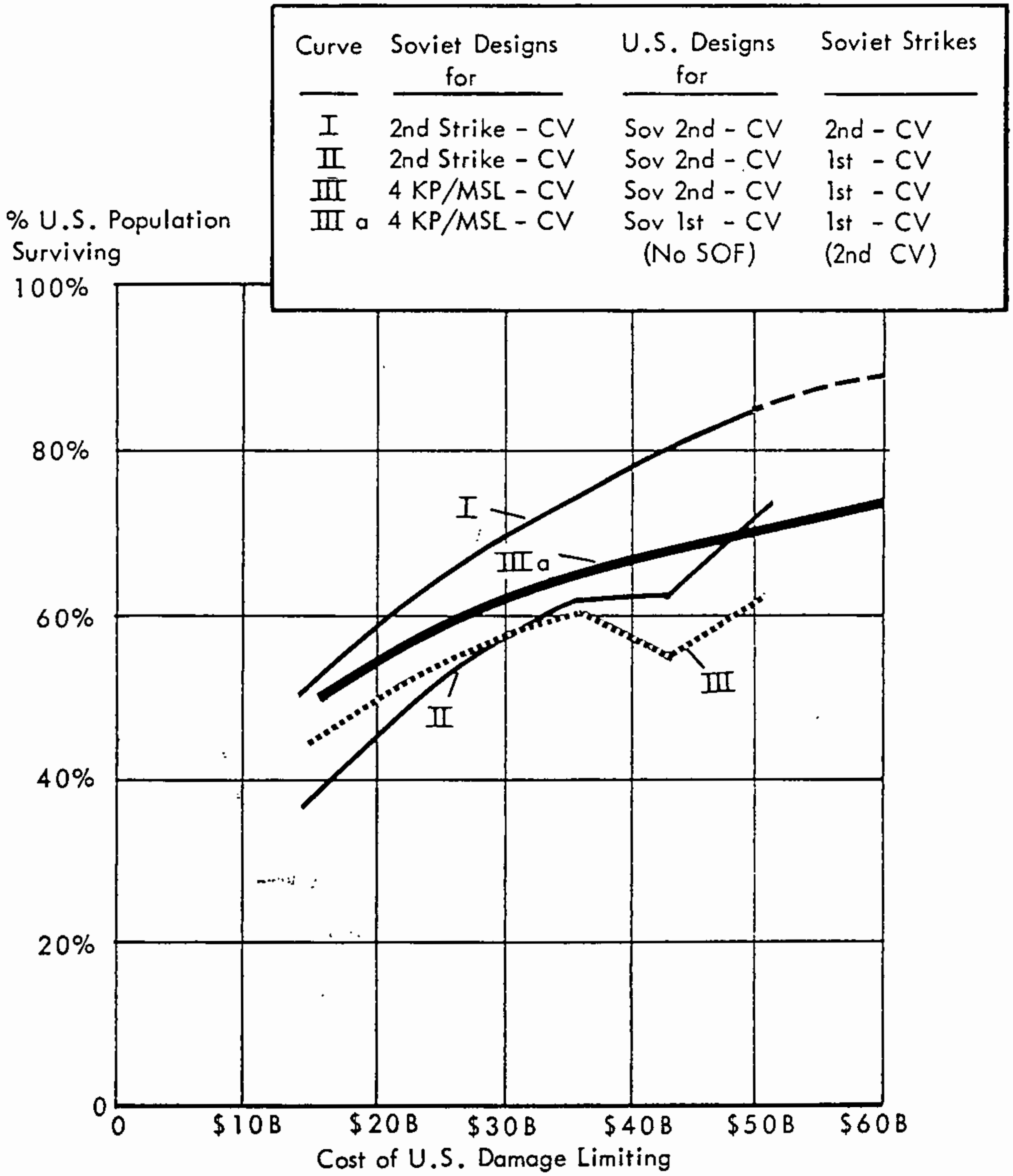

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Figure 22

% U.S. POPULATION SURVIVING vs. U.S. COST DAMAGE LIMITING for VARIOUS SOVIET-U.S. DESIGNS AND STRIKE STRATEGIES

Purpose

1. This graph illustrates several variations of Soviet-U.S. designs of counter-value and damage limiting forces respectively and what happens if a strategy is used other than that for which allocations have been designed.

Basis for Computation

2. For Curve I and II the Soviets ICBMs are designed from Figure 8. Soviet second strike design is from the optimal curve. Also shown in Curves III and IIIa are examples of Soviets deploying 4 KP missiles--independent of considerations of U.S. SOF. ICBM cost of Soviet attack is the same for each case. Soviet design for first strike counter-value will be treated on Figure 22a.

3. U.S. allocates optimally. For Curves I and II the allocations are those of Figure 19. For Curve III the allocations are similar to those of Figure 19. When U.S. is designed for Soviet first strike counter-value, Curve IIIa, the U.S. damage limiting forces do not contain SOF.

4. Case I is the nominal case and is the same as in Figure 18a, Curve B.

5. Case II gives the percent U.S. population surviving in the case that the Soviets have designed for second strike as in paragraph 2 above, but then use all of the inventory kilopounds in first strike counter-value (a limiting case). If the Soviets use part of their forces on counter-military targets in first strike (but not in second strike), the first strike/second strike differences would be less.

6. Case III gives the percent U.S. population surviving if the Soviets essentially ignore the influence of U.S. SOF on their packaging and use 4 KP/missiles. The U.S. is still designed for Soviet second strike.

7. Case IIIa is the same as Case III, except that U.S. is designed optimally for Soviet first strike and does not allocate funds to SOF. Since no forces are allocated to SOF, this curve applies to Soviet first or second strike.

Basic Points

8. It is recalled that in the Soviet second strike design, only about 22% of the Soviet ICBM kilopounds survive (a result of the optimum solution). Therefore, for Case I the Soviets have 1/.22 or about 4.5 as many kilopounds available for counter-value in first strike as in second strike. The attack results in 14% less U.S. population surviving than in the nominal case (second strike) over a wide range. The curve for Case II flattens out at about $38 B U.S.

expenditure because the U.S. is not optimized against this attack. A substantial part of U.S. funds have been expended on SOF which have no utility in this case.

9. A similar computation in the case of a $24 B (ICBM), $16 B (SLBM) and $9 B (BOMBER) Soviet budget shows:

$ U.S. Damage Limiting	Outcome, U.S. Population Surviving	
	Case I	Case II
$54.5 B	80%	56%
$65.0 B	85%	66%

10. Case IIIa, U.S. design for Soviet first strike counter-value, is about 5% to 12% higher than for Case II or Case III (whichever is lower).

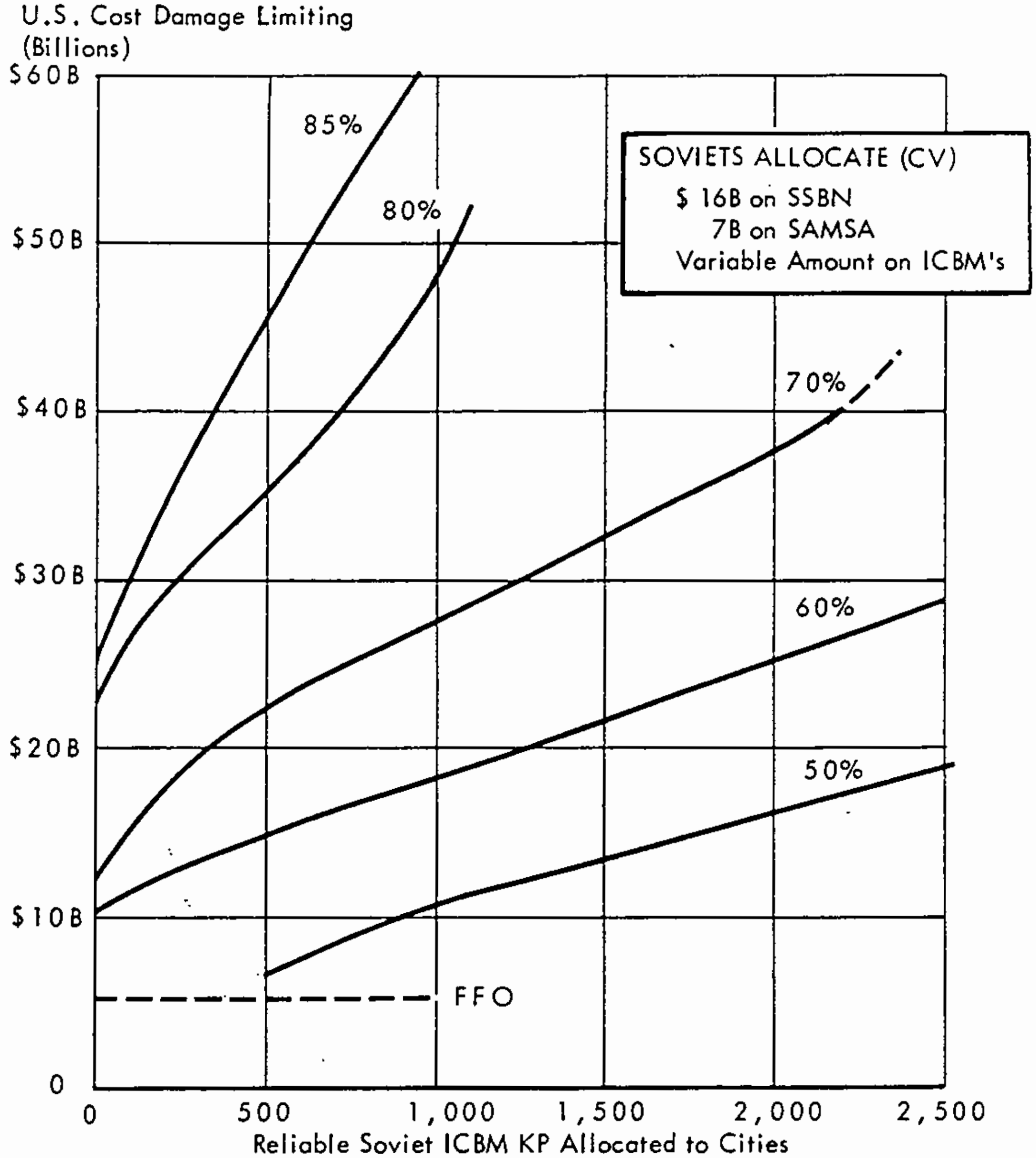
11. The U.S. can do considerably better (around 5% to 12%) by designing for Soviet first strike if the Soviets strike first. In doing so--designing for Soviet first strike--the U.S. would give up the opportunity of doing about 14% better for the case of Soviet second strike.

[redacted]

Figure 22a

U. S. Cost Damage Limiting
vs
Reliable Soviet ICBM KP Allocated to U. S. Population Targets for Constant % U. S. Population Surviving

Soviet First Strike Counter-Value



[redacted]

Figure 22a

RELIABLE SOVIET ICBM KP NEGATED vs. U.S. COST DAMAGE LIMITING

for CONSTANT % U.S. POPULATION SURVIVING

SOVIET FIRST STRIKE COUNTER-VALUE

Purpose

1. To show the relationship--for U.S. allocations designed for Soviet first strike counter-value (CV)--between the cost of U.S. damage limiting (to achieve a given level surviving) and the number of forces (KP) the Soviets allocate to counter-value targets.

Basis for Computation

2. In this case, some portion of the Soviet inventory of nuclear delivery vehicles could be expected to be allocated to military (non-CV) targets. The dominant variable in U.S. damage limiting allocations is then the absolute amount of KP used against cities, independent of the size of Soviet inventories. For Soviet design for first strike, this payload could be deployed in large packages, soft sites--more KP/Soviet dollar than in Soviet second strike designs.

3. The Soviet threat used for this graph is composed of (1) 100 SAMSAs arriving at CONUS, (2) 100 SSBN in inventory (deployed in a "normal" steady-state POLARIS-type operation) and (3) a variable amount of ICBM KP allocated to counter-value targets. (To simplify this case Soviet SSBN and aircraft are all allocated counter-value.)

4. The allocations to CD, ABD and ASW are the <u>same</u> as in Figure 19--second strike case. However, the Soviet (inventory) cost to generate 100 SAMSA over CONUS is less for first strike. Soviet ICBMs are negated by BMD only. (The utility of SOF in this case is discussed below.)

5. For zero Soviet ICBM KP allocated to U.S. cities, the U.S. costs are divided optimally between ABD/ASW/TD/FFO to negate the effects of Soviet SSBN and SAMSA. As Soviet ICBM KP are added to the attack, the U.S. negates these additional KP by buying additional TD; (that is, no SOF).

<u>Basic Points</u>

6. On this graph, the U.S. allocates optimally against the Soviet threat with knowledge of how many ICBM KP are used counter-value. If a different number of ICBM KP arrive than the U.S. allocated for, the percent U.S. population surviving would change from the "design value." This off-design behavior can be <u>approximated</u>--using this graph--by holding the U.S. budget level fixed at a "design point" and interpolating between curves to get the percent surviving corresponding to the KP arriving. For example, if the U.S. designs for 70% U.S. population surviving against an expected 750 reliable ICBM KP, but the Soviets actually use 2050 KP, the percent U.S. population surviving would be approximately 60%.

7. For larger attacks than shown on this graph, the U.S. costs would increase at the margins shown on Figure 17 (BMD only accommodating the larger attack).

8. The utility of SOF in this case depends upon the residual occupancy of Soviet ICBM sites (Soviet withheld reserve, or missiles that did not get off before U.S. SOF arrived) and on the (reliable) KP deployed per Soviet aim point. For SOF to mix with other damage limiting forces shown on this graph, there is a <u>minimum</u> residual occupancy of Soviet sites. Mixing also depends on the level of surviving U.S. population:

% U.S. Population Surviving	Minimum Occupancy for SOF to Mix*	
	4 KP/Aim Point	10 KP/Aim Point
50%	.72	.29
60%	.41	.16
70%	.26	.10
80%	.12	.05
85%	.07	.03

*If the residual occupancy of Soviets sites is greater than or equal to the number shown, SOF mixes and the U.S. allocates 1 reliable missile per Soviet site, covering all sites--no knowledge is assumed about which sites are occupied. These values presume no attrition of U.S. SOF.

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Figure 23

% Soviet Population Surviving
vs
MT Delivered Against Soviet Cities

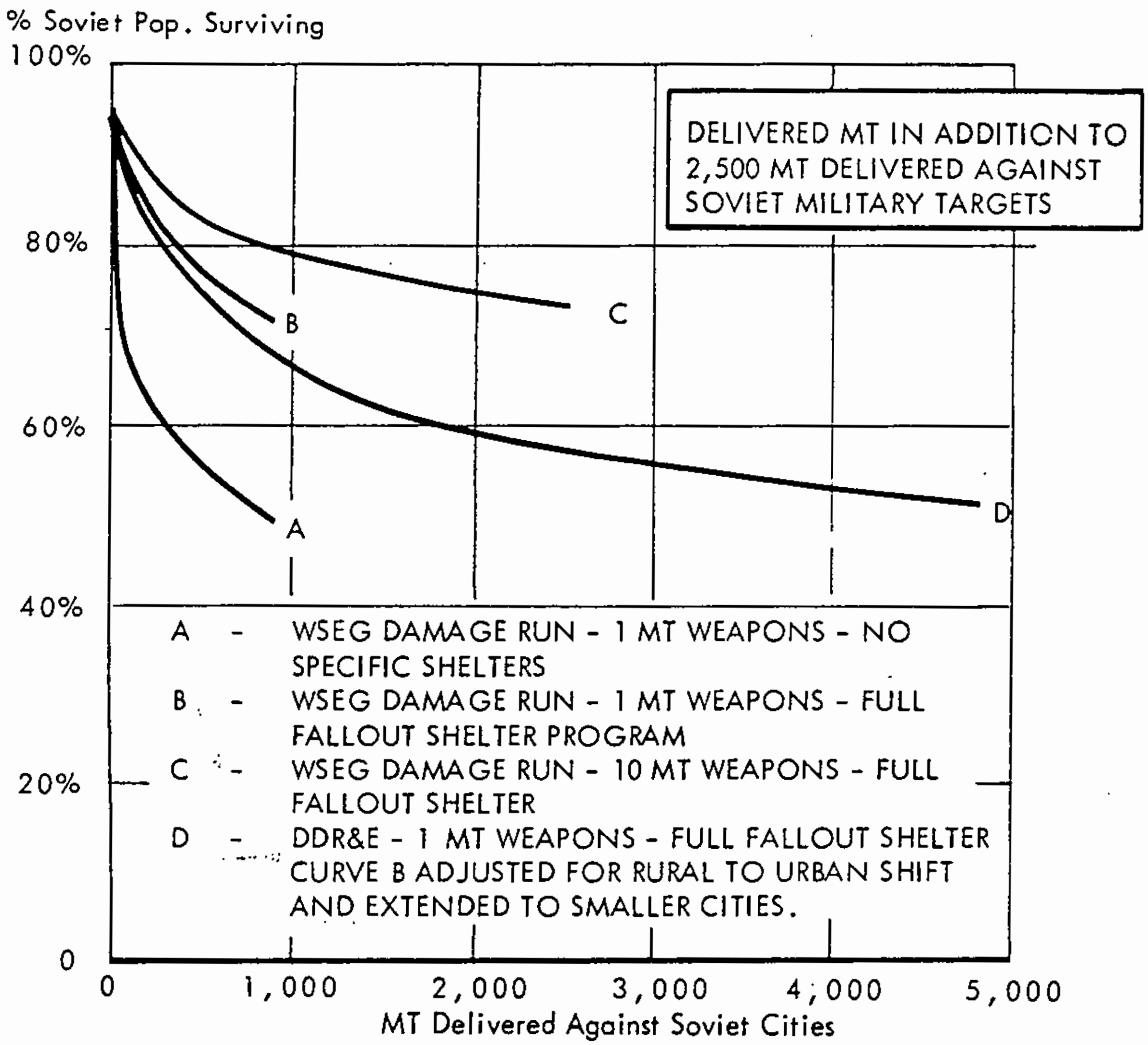

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Figure 23

% SOVIET POPULATION SURVIVING vs. MT DELIVERED AGAINST SOVIET CITIES

Purpose

1. To show the effect of fallout shelters and rural-urban population shift on vulnerability of Soviet population to attacks on Soviet cities (in addition to a 2500 MT military attack).

Basis for Computation

2. Basic data from WSEG report.

3. Weapons for both military attack and city attack are 50% fission. All weapons are surface burst.

4. Military attack is targeted to avoid collateral population fatalities. City attack is targeted to maximize fatalities.

5. Curves A, B and C are based on 1959 population distribution summarized in Figure 1. The WSEG counter-city attack targeted the first 306 cities from this distribution. These 306 cities contain 58 million people or 28% of the total population.

6. Curve D is based on Curve B (1 MT weapons, full fallout shelter program) but modified in two ways. First, Curve B was adjusted to account for population and area browth of Soviet cities predicted for 1970, as shown in Figure 1. This adjustment yielded the portion of Curve D up to about 1000 1 MT weapons. Second, Curve D was extended to cities

of less than 50,000 population by applying an everage of one and a quarter 1 MT weapons to each city. Comparison of weapon effects radius and city size indicates that this targeting will result in 90% fatalities in each city so targeted. A small number of fallout casulaties from these additional weapons was estimated from various WSEG runs and included.

7. The following table relates the percent Soviet total population surviving to the percent Soviet urban population surviving at the indicated number of MT delivered against Soviet cities (Curve D):

MT	% Total Population Surviving	% Urban Population Surviving
50	90%	85%
325	80%	67%
790	70%	50%
1625	60%	32%
~5500	50%	15%

Basic Points

8. The Soviet Full Fallout Shelter program allows about 22% more of the total Soviet population to survive. This holds approximately for all U.S. military and city attacks considered. Compare Curves A and B.

9. Adjustment of damage curves for the urban-rural shift results in approximately 25% fewer megatons required at 75% Soviet population surviving. Compare Curves B and D.

10. In order to achieve a percent Soviet population surviving of less than 70%, one must target small cities. See Curve D beyond 1000 MT delivered.

Figure 23a

U. S. KP ARRIVING AT TERMINAL DEFENSE vs SOVIET TD COST FOR CONSTANT % SOVIET POPULATION SURVIVING

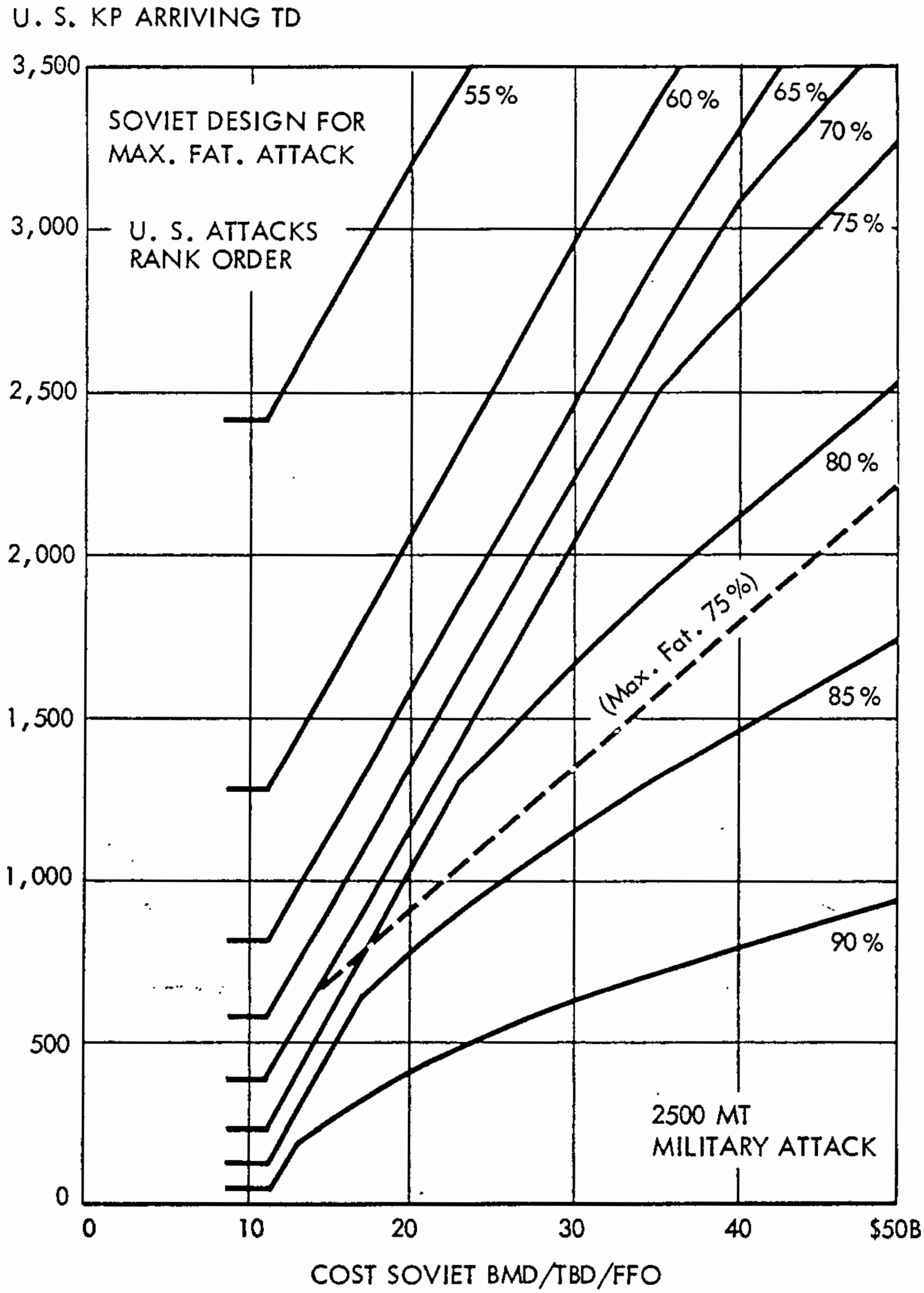

Figure 23a

U.S. KP ARRIVING AT TERMINAL DEFENSE vs. SOVIET TD COST FOR CONSTANT % SOVIET POPULATION SURVIVING

Purpose

1. To show the utility of active terminal defense, (BMD/TBD) with FFO, in negating the effects of incoming payload for constant levels of population surviving. This figure is to be compared with Figure 17 for the U.S. case.

Basis for Computation

2. The Soviet is given a NIKE-X BMD system. Basic data on NIKE-X is from the Army study.

3. NIKE-X cost is $2.4 B plus $2.0 million per object shot down. Soviet deployment is designed for interceptor exhaustion against a U.S. attack structured for maximum Soviet population fatalities. The minimum size battery is somewhat smaller than U.S. case and shoots down 25 objects.

4. TBD is interlocked at 20% of BMD cost just as in the U.S. case, see Figure 15a. FFO for Soviet was costed by OCD at $8.7 B for 270 million spaces.

5. U.S. attack is structured in rank order of population. U.S. missiles use 1 MT weapons (average 0.73 KP per weapon) on undefended cities and 0.1 MT multiple warheads (average 0.20 KP per warhead) on defended targets. Although the optimum size multiple warhead varies with the total BMD budget, the multiple

warhead chosen is close to the optimum over most of the range of BMD deployments presented.

6. Below 60% Soviet population surviving the data on Figure 23 a is also applicable to a U.S. attack structured for maximum fatalities. The dotted line shows a typical result for a U.S. attack structured for maximum fatalities at 75% Soviet population surviving.

Basic Points

7. For U.S. attack sizes and Soviet BMD/TBD/FFO costs corresponding to the curved portion of the curves on the graph, the U.S. rank order attack does not target all of the defended cities.

8. For rank order attacks that target all defended cities the Soviet marginal cost (investment plus 5 year operation) per U.S. kilopound negated is $11.4 M including the cost of TBD interlock and $9.6 M for BMD alone. These costs refer to the straight line portion of the curves on the graph.

9. To achieve 75% Soviet population surviving at Soviet BMD/TBD/FFO costs above $35 B requires about 1000 KP more for a rank order attack than for a maximum fatality attack.

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Figure 24

% Soviet Population Surviving
vs
Soviet Cost for Damage Limiting
U.S. Second Strike Counter-Value

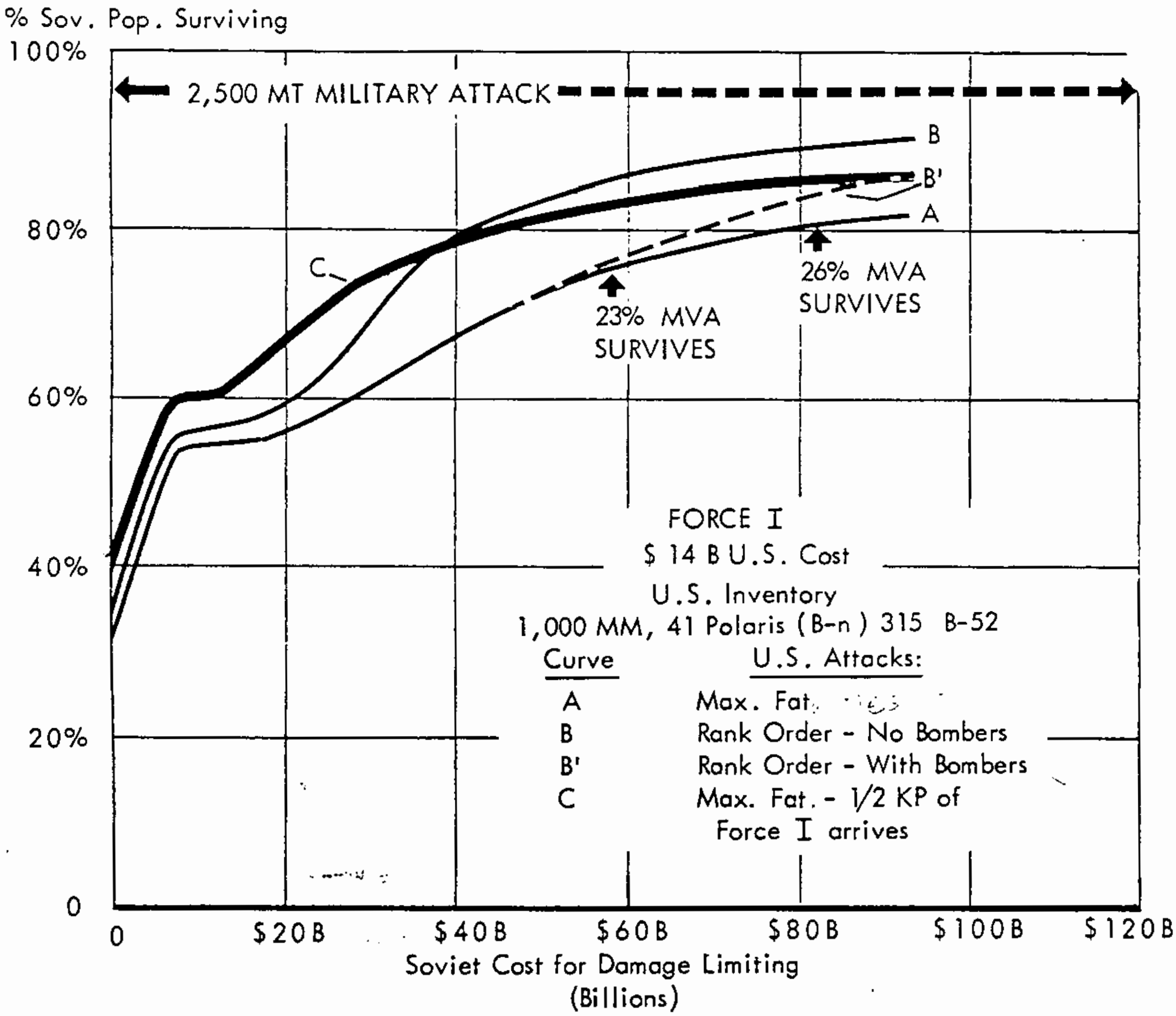

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Figure 24

% SOVIET POPULATION SURVIVING vs. SOVIET COST

FOR DAMAGE LIMITING (OPTIMIZED)

U.S. SECOND STRIKE COUNTER-VALUE

Purpose

1. To show, for a fixed U.S. force, the level of Soviet population surviving vs. Soviets cost for optimum Soviet allocations to all available means of limiting damage. The calculations are shown for different types of attack by U.S. A case where there are no U.S. bombers is also shown.

2. This case was chosen to illustrate some nominal, mixed U.S. forces--to bring into play all types of damage limiting forces.

Basis for Computation

3. As described in Figure 17 (for the corresponding U.S. case), optimum allocations were made at each level of population surviving on the basis of equating marginal costs for all means of limiting damage. The marginal costs were computed from the utility graphs for each type of force with careful attention paid to entry price phenomena.

4. The U.S. Force I is as follows:

System	Cost	Inventory	Reliable kilopounds Arriving Soviet Defenses
MM II	$ 3.9 B	1000	900
POLARIS (B-n missiles)	$ 4.7 B	41 boats (16 missiles/boat)	1200
B-52 (with SRAM)	$ 5.8 B	315 (18 SRAM/bomber)	600*
TOTAL	$14.4 B		2700

*Equivalent kilopounds at the rate of 4 kilopounds per bomber.

[redacted]

80 - FOI-985 (2)

[redacted]

Operational factors are given in Figure 9 for missiles and in the Air Force study for the B-52. The choice of B-n over A-3 missiles for POLARIS is based on the following consideration: A 41 boat POLARIS (B-n) force costs only about $1.5 B more than a 41 boat POLARIS (A-3) force but has 800 more reliable KP arriving at the Soviet Defenses. The Soviet BMD cost to offset these additional 800 KP is approximately $8 B if the percent Soviet population is less than 70% or if the U.S. targets in rank order. For other cases the Soviet BMD cost is more than $8 B.

5. The calculations are based on fixed U.S. forces and do not attempt to minimize percent Soviet population surviving by changing the mix of U.S. forces depending upon Soviet allocations.

6. Soviet forces available for damage limiting consist of

   a. the SS-small (essentially a Soviet version of Minuteman) with an assumed SSP_k of Leaving aside multiple, individually guided R/Vs, this is the best Soviet choice for attacking the U.S. ICBMs.

   b. a Soviet version of NIKE-X, costed identical to U.S. NIKE-X, namely $2.4 billion plus $2 million per object shot down. These costs were derived directly from the Army study.

[redacted]

c. Terminal Bomber Defense (AADS-70) interlocked with Ballistic Missile Defense plus additional batteries (HAWK) in smaller cities to force use of SRAM missiles by bombers.

d. Area Bomber Defense based on Air Force study but with costs for a given attrition reduced to 1/3 to account for costs to defend only that portion of Soviet Union containing 90% of its population.

e. No Soviet ASW forces.

f. Full Fallout Shelter, OCD estimate of $8.7 B for 272 million spaces. As in the U.S. case, this was provided first.

7. The campaign consists of a Soviet missile strike: on U.S. ICBMs (100% occupancy); on POLARIS in port (20% of submarines); and on bomber bases (50% of B-52 bombers not on alert). U.S. forces that survive are directed against Soviet Union population centers. There is a concurrent 2500 MT U.S. attack against Soviet military targets.

8. U.S. missiles use multiple warheads (0.1 MT, 0.2 kilopounds) on defended targets and 1 MT warheads (average 0.73 kilopounds per 1 MT) on undefended targets. For assured destruction multiple warheads are used rather than decoys which might not work. Note: It was determined that the optimum multiple

warhead yield varies with the Soviet BMD budget. The multiple warhead that was used is near optimum over the range of Soviet BMD deployments considered.

9. U.S. bombers carry 15 reliable Short Range Attack Missiles (0.20 MT yield each). One bomber payload of this type is the equivalent (in producing fatalities) of about 4 kilopounds of missile payload (with 1 MT weapons).

10. For Curve A all forces listed in paragraph 4 are targeted jointly to produce maximum fatalities. For Curve B the bombers were omitted and the POLARIS and ICBM forces targeted against Soviet cities in rank order of population. For Curve B' the bombers were added to the rank order attack of Curve B.

11. For Curve C one-half of the forces listed in paragraph 4 were targeted for maximum fatalities.

Basic Points

12. Soviet damage limiting against the full U.S. force attacking for maximum fatalities, Curve A, required large expenditures.

% Soviet Population Surviving	Soviet Cost	Ratio of Soviet Cost to U.S. Cost
60%	$28 B	2.0 : 1
70%	$45 B	3.2 : 1
80%	$82 B	5.9 : 1

This will be discussed further in Figures 26 and 27.

13. For Curve B' the missiles are targeted in rank order of population and the bombers are targeted for maximum fatalities against the undefended region. Curve B' gives the same results as targeting for maximum fatalities, Curve A, up to $50 B Soviet costs. Above that expenditure the rank order attack results in fewer Soviet fatalities. This implies that, for Curve A, some of the BMD/TBD defended region is not being targeted when the Soviets spend more than $50 B.

14. Constraining the attack to rank order with missiles only, Curve B, results in an increase (over the full force targeted for maximum fatalities, Curve A) of 10% in percent Soviet population surviving over most of the range of Soviet costs.

15. Reduction by one-half in U.S. forces arriving at Soviet urban-industrial targets, Curve C, results in a reduction in Soviet costs from Curve A by slightly less than one-half for the same level of damage.

% Soviet Population Surviving	Soviet Cost Full U.S. Force I	Soviet Cost One-half U.S. Force I
	Curve A	Curve C
65%	$35 B	$19 B
70%	$45 B	$23 B
75%	$57 B	$31 B
80%	$82 B	$47 B

[redacted]

Figure 25

% Soviet Population Surviving
vs
Soviet Cost for Damage Limiting
U.S. Second Strike Counter-Value

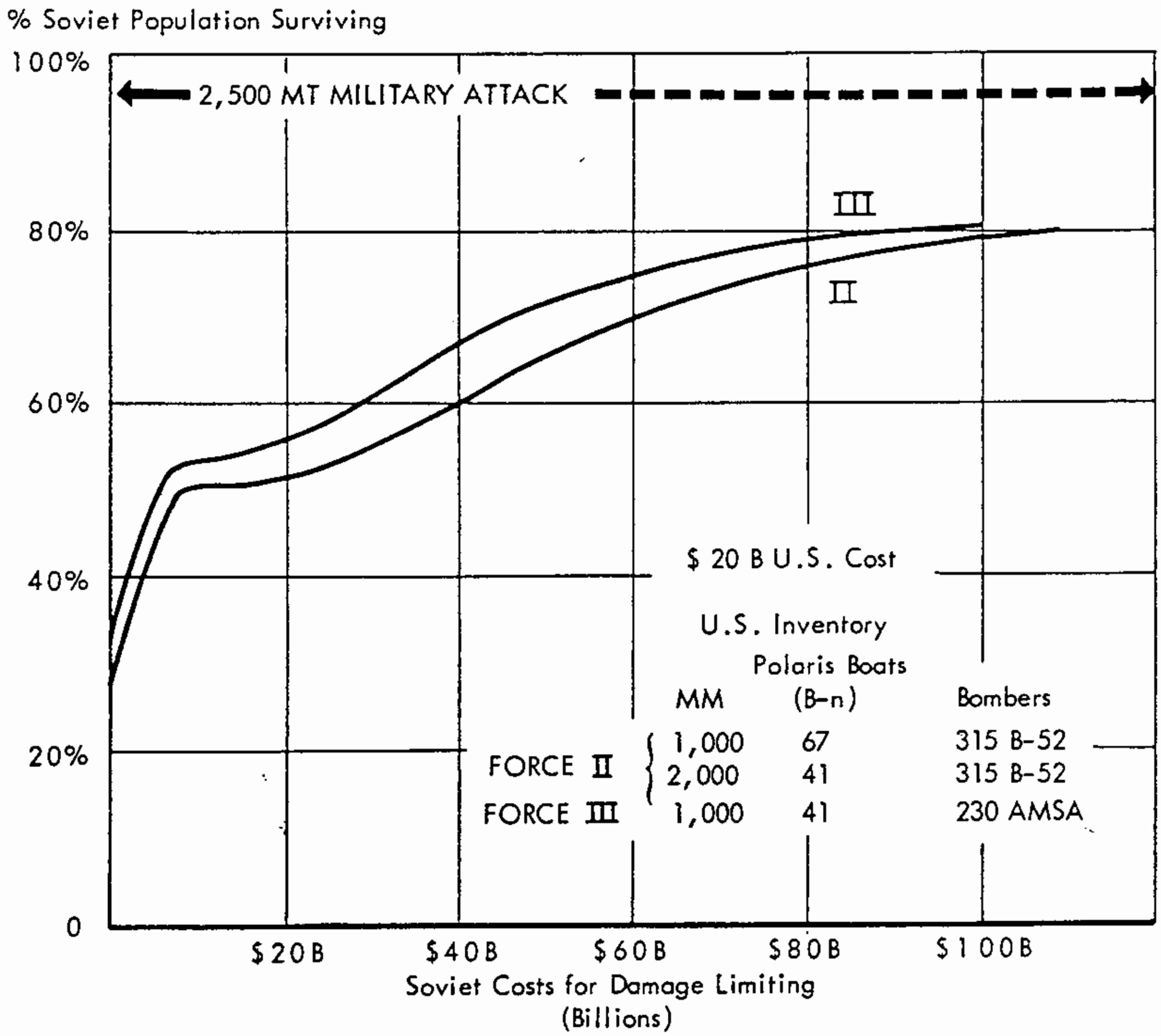

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Figure 25

% SOVIET POPULATION SURVIVING vs. SOVIET COST

FOR DAMAGE LIMITING

U.S. SECOND STRIKE COUNTER-VALUE

Purpose

1. To show the relative utility of increasing the level of various U.S. forces allocated to counter-value targets.

Basis for Computation

2. Basic method and data outlined in Figure 24.

3. For Curve II the $5.3 billion was used to augment the missile forces of paragraph 4 of Figure 24. This produced the following alternative forces:

Force II A

System	Cost	Inventory	Reliable Kilopounds Arriving at Soviet Defenses
MINUTEMAN II	$19.2 B	2000 MSLS	1800
POLARIS (B-n)	$ 4.7 B	41 Boats	1200
B-52 (SRAM)	$ 5.8 B	315 A/C	600*
TOTAL	$19.7 B		3600

FORCE II B

System	Cost	Inventory	Reliable Kilopounds Arriving at Soviet Defenses
MINUTEMAN II	$ 3.9 B	1000 MSLS	900
POLARIS (B-n)	$10.0 B	67 Boats	1950
B-52 (SRAM)	$ 5.8 B	315 A/C	600*
TOTAL	$19.7 B		3450

*Equivalent kilopounds at 4 kilopounds per bomber.

Force II A and II B resulted in essentially identical results, Curve II.

[redacted]

4. For Curve III the B-52s were replaced by AMSAs. The $5.3 B, together with the $5.8 B-52 budget--a total of $11.1 B-- was used to buy AMSA bombers. This produced the following force:

Force III

System	Cost	Inventory	Reliable Kilopounds Arriving at Soviet Defenses
MINUTEMAN II	$ 3.9 B	1000 MSLS	900
POLARIS (B-n)	$ 4.7 B	41 Boats	1200
AMSA (SRAM)	$11.1 B	230 A/C	600*
TOTAL	$19.7 B		2700

*Equivalent kilopounds at 4 kilopounds per bomber.

The ratio of equivalent reliable kilopounds arriving at Soviet defenses per inventory aircraft is higher for AMSA than for B-52. This results primarily from higher dispersal and alert rate (33% non-alert). The higher penetration probability of AMSA results in such high Soviet Area Bomber Defense marginal costs that no Soviet ABD was purchased within the limits of Soviet budgets examined.

Basic Points

5. An increase in U.S. forces for counter-value may be made equally well with POLARIS (B-n) or MINUTEMAN II. (Due to lack of inputs from Service component studies ICM defended with hard point defense was not considered.)

6. An increase in the U.S. allocation to bombers, applied to AMSA with SRAM, does not give as high a utility for counter-value as the same increase applied to missiles. The curve for Force III

[redacted]

[redacted]

($11 B on AMSA) lies only slightly below Curve A of Figure 24 for Force I ($6 B on B-52 with SRAM). This stems from the large "entry" price for AMSA compared to B-52s. Only O&M costs are charged to B-52s whose investment costs are sunk.

7. A rank order attack with multiple warheads can be looked at as follows. The Soviet cost to negate a kilopound of missile payload is approximately $10 million, ($2 million per object shot down) x (5 multiple warheads per U.S. missile kilopound). The U.S. cost per reliable kilopound deployed in new POLARIS (B-n) is about $7 million/KP. Thus, the U.S. can track Soviet BMD expenditures (and maintain a given level of assured destruction) at about the ratio of (0.7 : 1.0), for additional (incremental) U.S. costs to additional Soviet costs.

8. Curve A of Figure 24 and Curve III of Figure 25 refer to mixed U.S. forces. The Soviet damage limiting costs would be approximately the same as Curve A for a U.S. pure missile force costing the same, $14 B, as the mixed force. Correspondingly, Curve III is approximately the result for a U.S. pure missile force costing $15 B as opposed to $20 B for the mixed force. A better SRAM or, equivalently, a higher Soviet cost to prevent bombers from undercutting Soviet BMD would raise the relative utility of these mixed forces.

9. Curve II also represents the damage inflicted by a $20 B U.S. force consisting of 1000 MINUTEMAN II, 41 SSBN, 315 B-52 and 48 Ballistic Missile Ships (B-n) using the Navy study results for counter-action against BMS ships.

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Figure 26

% U.S. or Soviet Population Surviving
vs
Ratio of $ Cost U.S. (or Soviet) Damage Limiting to $ Cost Soviet (or U.S.) Damage Creating

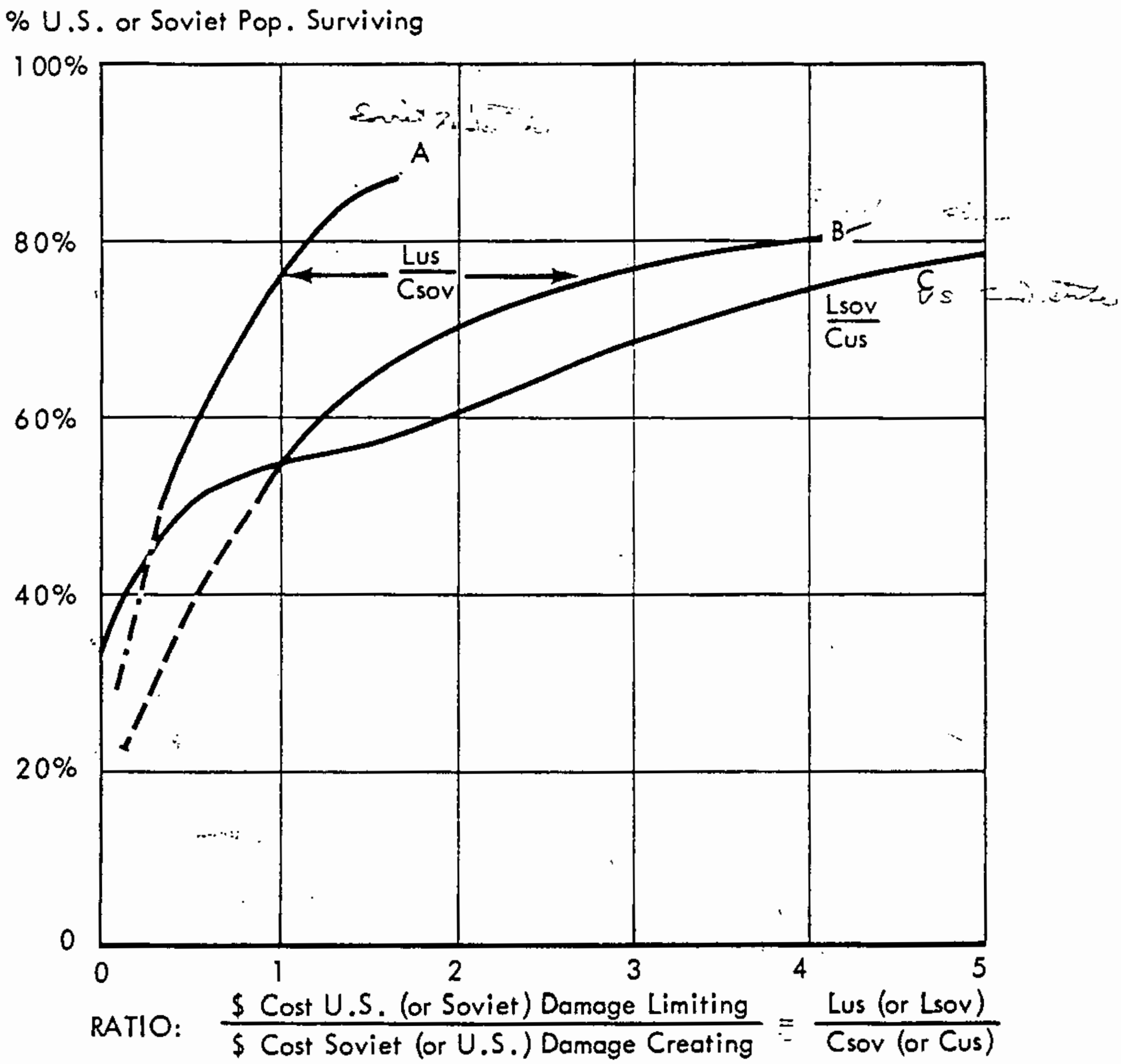

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Figure 26

% U.S. OR SOVIET POPULATION SURVIVING vs. RATIO OF $ COST U.S. (SOVIET) FOR DAMAGE LIMITING TO $ COST SOVIET (OR U.S.) FOR DAMAGE CREATING

Purpose

1. This graph shows the results of aggregating into one ratio the costs of damage limiting for the "defender" and the associated costs of damage creating for the attacker, and the outcome in percent population surviving.

Basis for Computation

2. For the U.S.--Curve A represents a Soviet second strike counter-value. It is computed from Figure 18a by dividing the cost of U.S. damage limiting by the appropriate total cost of the Soviet threat. Curve B represents a case of Soviet first strike counter-value. It is computed from Figure 22a, with ICBM KP costed as SS-7s (4 KP).

3. Additional cases for which optimized solutions were calculated ranged over combinations of the following Soviet threats:

Soviet ICBM Budget	Number of POLARIS-type SSBN	Number of SAMSA/SUBSONIC
$5 - $30 billion	0 - 100	0 - 200/0 - 400

These cases represent points lying mainly between or very close to Curves A and B.

4. For the Soviet Union--Curve C represents a U.S. second strike. It was computed by aggregating data from Figure 24 and 25 (Curves A and II respectively).

5. Soviet costs are essentially computed as U.S. dollar costs for systems bought from U.S. manufacturers. The ratios are thus representative, in these terms, and do not represent the relative strain on the two economies.

<u>Basic Points</u>

6. This graph aggregates the results of damage limiting calculations using the observation that the ratio of expenditures--damage limiting to damage creating--represents outcomes (percent surviving) over wide variations of the threat. This is especially true for a given <u>relative</u> mix of attacking forces under a given scenario.

7. The ratio, at a given "% Surviving," does depend on (1) the scenario--e.g., the occupancy of SOF targets, first or second strike counter-value attacks--(2) the situations each side designs for--and (3) the mix of damage creating forces.

8. For the type and mixes of Soviet forces considered in this study, a pure Soviet ICBM force would produce the largest ratio L_{us}/C_{sov} for the U.S. for a given percent U.S. surviving. If Soviet POLARIS-type submarines increase their payload, or decrease their noise level from the

nominal case considered, the Soviet submarine threat would be competitive with missiles in making the ratio higher. Subsonic Soviet bombers would produce the same utility at less cost than SAMSAs for the U.S. air defenses considered here.

9. Over most of the range, the cost ratio to achieve a given percent surviving is lower for the U.S. than for the Soviet Union. This asymmetry will be examined on the next graph.

10. This analysis does not take into account poor Soviet planning (except for the relative mixture of types of offensive forces--see paragraph 8). Poor planning on the part of the Soviets would lower the ratio, L_{us}/C_{sov}, for a given percent U.S. population surviving.

[redacted]

Figure 27

% U.S. or Soviet Population Surviving
vs
Ratio of $ Cost U.S. (or Soviet) Damage Limiting to $Cost Soviet (or U.S.) Damage Creating

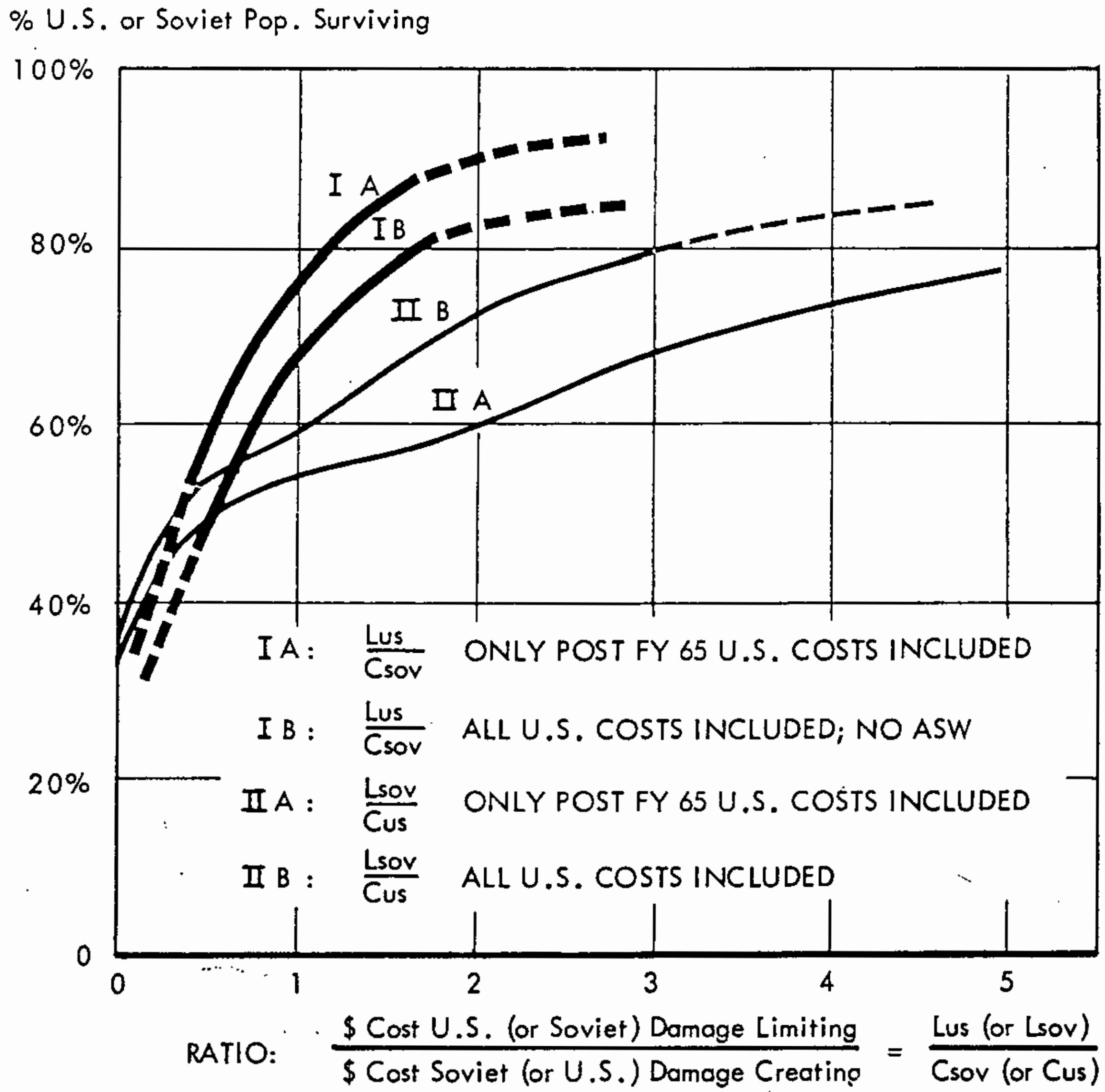

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Figure 27

% U.S. OR SOVIET POPULATION SURVIVING vs. RATIO

OF $ COST U.S. (OR SOVIET) DAMAGE LIMITING

TO $ COST SOVIET (OR U.S.) DAMAGE CREATING

Purpose

1. Same as Figure 26, but to explore U.S.-Soviet assymmetries. This graph shows the results of aggregating the costs of damage limiting for the defender (one nation) and the associated costs of damage creating for the attacker (the other nation) and the outcome in percent population surviving.

Basis for Computation

2. Curve I A was computed from Figure 18a (same as Curve A on Figure 26).

3. Curve I B represents the results of (1) removing ASW from the means of damage limiting, (2) re-allocating--optimally--damage limiting resources to the other means of damage limiting and (3) including FY 65 and prior costs. This calculation--and that described in paragraph 4 below--was made in order to compare the U.S. and Soviet damage limiting cases on the same basis--that is, without ASW and using all costs (both pre-FY 65 and post-FY 65) for SOF, ABD and BMD/TBD/FFO.

4. Curve II A was computed from Figures 24 and 25 (Curves A and II respectively) by dividing the post-FY 65 cost of Soviet damage limiting by the post-FY 65 cost of U.S. damage creating.

5. Curve II B was calculated from Curve II A by re-costing the U.S. damage creating forces as if they were to be procured in the future (new buy). This re-costing applies to 41 SSBNs and 1000 MM II. B-52s were replaced by 230 AMSAs.

<u>Basic Points</u>

6. From the U.S. damage limiting/assured destruction posture as derived from the end FY 65 funded forces, the U.S. has significant advantages over the Soviets both in damage limiting and assured destruction. (Note: assured destruction of the Soviets by the U.S. is equivalent to Soviet damage limiting.) For example, if both the U.S. and the Soviets spend (post-FY 65)--to limit damage--1.5 times the amount the other spends to create damage, then about 84% of the U.S. population would survive (Curve I A) and only about 57% of the Soviet population would survive (Curve II A).

7. The asymmetry in the above outcome stems from: (1) a large part of the U.S. forces have been funded through FY 65 and these costs are not included; (2) the U.S. uses ASW against a relatively unsophisticated Soviet submarine while the Soviets do not conduct ASW against U.S. SSBNs; (3) asymmetries in population densities and distributions.

8. When U.S. ASW is excluded and all remaining U.S. forces are costed on the basis of a new buy, the large asymmetry disappears but the U.S. still is somewhat better off. In this case, if each nation spends 1.5 times--to limit damage--as much as the other does to create damage, then about 78% of the U.S. population and 67% of the Soviet population survives.

9. At low values of the ratio of the abscissa, the larger Soviet rural population gives the Soviets the advantage over the U.S. in terms of total population surviving.

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Summary

This study demonstrates that the U.S. can, within reasonable costs and with appropriate choices, maintain a significant potential to limit damage to the U.S. while retaining a capability for assured destruction of the Soviet Union. The study is essentially time independent and does not address such problems as the time sequence of allocations necessary to reach given postures. The study mainly focuses on the total potential counter-value threat as seen by both sides.

Balanced Defenses

While this study illustrates that there does not exist a unique balanced posture for damage limiting, it does focus attention on those judgments and considerations which affect both the outcomes and the allocations made. Given the non-economic judgments and considerations, it is possible to construct balanced allocations. A balanced defense, in the context of this study, is one where an additional unit of effort or expenditure on any one of several damage limiting forces would bring the same return -- at each overall level of effectiveness. That is, at a given percent U.S. population surviving, an additional dollar allocated to one damage limiting force will bring the same decrease in damage -- or increase in survivors -- as that same dollar allocated to any of the other forces. Conversely, an unbalanced defense implies that there is some force (or forces) for which an additional dollar would bring a large return compared to the return gained by adding it to the others. For every balanced allocation there is a fairly broad range of "near balanced" or "near optimum" allocations over which it is possible to apply other criteria: judgments, hedging against performance or outcome uncertainties, and against off-design cases.

Designs of Balanced Defenses

The fundamental choice in the design of balanced defense is the selection of those situations for which the country is to prepare itself. The study considers large-scale counterforce and countervalue campaigns, first and second strike, and the appropriate preparations for them.

For these campaigns the analysis reduces the problem of allocations to the following set of considerations:

(1) The level of surviving value (i.e. population) designed for or planned for (how well you do). This level determines:

(a) The ratio of the cost to limit damage to the cost to the attacker to create damage. This ratio is the relative cost to maintain a given level of survivors. In general, the ratio is approximately independent of the size of the threat. It does depend on the attacker's relative force mixture and the quality of his planning.

(b) The level surviving also determines the marginal cost at which the defender is operating -- the additional cost to the defense per additional unit of threat, to maintain that level of survivors.

(2) The marginal cost of the defense (1b above) determines which damage limiting forces mix in constructing a balanced defense. It essentially sets the effort or expenditure per unit threat for each of the forces. Basically, the marginal cost of each of the damage limiting forces depends on its characteristics and technology and on the characteristics and technology of the damage creating forces.

(3) The size of the allocation made to a given damage limiting force, if it mixes, is determined by the size of the opposing damage creating force.

The strong influences on allocations, then, are those factors which drive the marginal costs, and the size of the threat which faces a particular type of damage limiting force. The factors driving the marginal costs of various damage limiting forces are discussed below. The characteristics of potential damage creating forces that are identified as driving the marginal costs of U.S. damage limiting forces are important factors in intelligence inputs for planning purposes.

U.S. Damage Limiting

U.S. Civil Defense

There is high utility in fallout shelter programs -- between 20% and 30% of the U.S. population are saved by a full fallout shelter program (a cost of $5.2 B) for a very wide range of attacks against military and/or population targets. This allocation is always included, except for designs for very low levels of surviving population or for very low levels of attack.

[redacted]

The specific blast shelter programs examined did not compete favorably with active terminal defense, from the standpoint of saving people and industry. However, specially designed programs mixing blast shelters and active defense may show higher utility than active terminal defense alone. This problem remains open at this time. The utility of blast shelters (and hence their marginal cost) depends on their occupancy -- the fraction of the people who make use of available shelter space. There are further uncertainties regarding post-attack emergence from shelters in blast damaged areas (the rubble problem).

U.S. Ballistic Missile Defense

A characteristic observed for terminal defense is that its marginal cost -- that is, the additional cost to negate the effects of an additional unit of incoming payload -- is approximately constant over a wide range of attacks or expenditures, keeping the level of survivors constant. (See Figure 17 and Figure 23a). The marginal cost varies with the level of surviving population. This behavior operates in the following way: (1) The level of surviving population being examined or designed for determines a marginal cost; (2) BMD can accommodate attacks at this margin; (3) this marginal cost "paces", in most cases, the margins at which other forces operate when "balanced". Because the marginal cost of Ballistic Missile Defense is a constant over a wide range of incoming threats, it does not determine -- as it does for other means of damage limiting -- the amount allocated to terminal

[redacted]

defense. The amount allocated to Ballistic Missile Defense is determined by the size of the threat arriving at the terminal defenses after other damage limiting forces operate.

The utility of Ballistic Missile Defense includes a virtual attrition effect -- the "lethal" payload per missile is reduced for missiles shot at the defense. For example, the attacker, in optimizing missile payloads for use against the defense, replaces a large single R/V with a mixture of smaller R/Vs and decoys. (In fact, the attacker's optimum packaging depends on the size of the BMD deployment).

The BMD deployments considered were designed for well-coordinated attacks maximizing overall fatalities -- the attacker either avoiding or penetrating the defenses, whichever gives the greatest kill. If the attack were carried out in rank-order of city population -- paying the "price" charged by the defense -- the utility of Ballistic Missile Defense would be greater. Deployments hedging against "ragged" attacks would have more interceptors per radar and would show greater utility against such attacks than the deployments used in the study.

The utility and hence the marginal costs of BMD depend on the nature of the attacks the defender plans for and are not necessarily those of the campaign. (See Figure 23a).

U.S. Bomber Defense

Bomber defenses in damage limiting play two important roles -- reducing damage by attrition of aircraft or aircraft delivered weapons, and preventing the undercutting of a large investment in ballistic missile defense.

It was observed that for Area Bomber Defense, the percent attrition is determined by the ratio of inventory interceptors to arriving bombers. This ratio is related to the number of interceptor passes made on each incoming bomber. The marginal cost of Area Bomber Defense depends on (1) the cost and technology of the bomber defense system; (2) the characteristics of the incoming bombers; and (3) the equivalent lethal payload of the bombers. Also, the marginal cost is inversely proportional to the fraction of bombers targeted counter-value. Area Bomber Defense has the bonus effect of protecting all targets. The utility of Area Bomber Defense is sensitive to whether or not Soviet bombers have an air-to-air missile capability against interceptors. The marginal cost sets the ratio (above) of interceptors to bombers; the size of the threat drives the size of the total allocation to Area Bomber Defense.

Terminal bomber defense displays the same general marginal cost characteristics described above for Ballistic Missile Defense -- i.e., for a given level of survivors, the marginal cost is constant for a wide range of attack sizes. Like Ballistic Missile Defense, the utility of Terminal Bomber Defense includes a virtual attrition effect. The attacker, in optimizing payload against defended targets, replaces bombs with air-to-surface missiles. A large part of the bomber payload then consists of rocket motors, et al, and the "lethal payload" is considerably reduced. The marginal cost is dependent on the number of missiles per bomber. This is particularly true in the sense that for advanced terminal defense technology the "price" of the target is measured by exhaustion of the defenses.

A thin terminal bomber defense deployment over many cities shows good utility in preventing serial bombing (many targets attacked by one bomber carrying many bombs) and in achieving the sizeable virtual attrition effect noted above. Area Bomber Defense and Terminal Bomber Defense are closely competitive. For a given effectiveness the combined Area and Terminal Bomber Defense cost is not very sensitive to the mix of the two types of forces. An expenditure of 20% of the cost of Ballistic Missile Defense deployments on Terminal Bomber Defense was used to interlock Terminal Bomber Defense and Ballistic Missile Defense -- i.e. to prevent undercutting of Ballistic Missile Defenses by bombers. Because of the lack of sensitivity, the additional allocations to combined Bomber Defenses were made on the basis of balancing the defenses with other types of damage limiting forces.

U.S. Anti-Submarine Warfare

The analysis focused on Anti-Submarine Warfare (ASW) against a Soviet steady-state POLARIS-type operation. The utility of ASW in negating the effects of SLBMs was perhaps the most complex problem studied. This complexity resulted from the fact the ASW forces include a highly mixed set of forces -- surface ships, submarines, land and sea-based air forces, and passive, underwater sound surveillance systems (SOSUS). The shape of ASW utility graph (Figure 12) -- the result of sub-optimizations among these mixed forces -- reflects the complex behavior.

In a sense this behavior depends on the initial force conditions -- what mix of forces are available with prior FY 66 funds. The initial forces are not "balanced" for the damage limiting objective in the sense of this summary study. Therefore, as the subsequent sub-optimizations progress, more SOSUS, for example, must be procured. The immediate effect of a new SOSUS buy-in is to flatten out the utility curve. As a result the marginal utility does not progressively decrease, but decreases and then increases again as "entry prices" are paid for each of the mix of ASW forces. This behavior destroys the concavity of the utility curve. As time goes on and if ASW forces are procured in a manned optimized for the damage limiting objective, the initial force mix will tend to be more "balanced" in the sense of this study. The utility curve would then show -- on subsequent examination -- a more concave behavior.

There are three important parameters which affect the relative utility of ASW as a means for damage limiting (i.e. drive the marginal costs): (1) Soviet SLBM range; (2) Soviet SSBN level of quieting; (3) Soviet SSBN loading -- the number of kilopounds of payload per submarine. The effect of increasing missile range from 1500 n.mi. -- the nominal case -- to 2000 miles is to raise the costs of ASW about 25% to achieve the same effectiveness. [redacted] Higher Soviet SSBN loading tends to decrease this marginal cost since ASW forces kill submarines and, the more kilopounds per submarine the more kilopounds of payload destroyed for the same cost. Improved noise characteristics and increased loading should be expected concurrently since both stem from advanced technology.

It should also be noted (Figures 19a and 19b) that ASW trades off closely with SOF and BMD over wide ranges of expenditures. Only mathematically optimum expenditures are carried forward. Other judgment factors such as utility of ASW in limited war or utility of surface ships in Anti-Submarine Warfare (ASW) were not examined in this study.

Strategic Offensive Forces

Missiles show a high damage limiting utility in destroying non-alert bombers and submarines in port, but no utility against submarines at sea or bombers that are on alert and can be flushed on warning.

In considering the duel of U.S. missiles against Soviet land based missiles a design concept was developed for balanced proliferation of the missiles being attacked. This concept maximizes the surviving Soviet missile payload for a fixed U.S. missile attack and a fixed Soviet budget, by choosing the size of the Soviet missile and the number of such missiles. Although a different size is optimum for each U.S. threat and Soviet budget, a single fixed size is near optimum over a wide range of threats and budgets. There are other ways that the Soviet can attempt to maximize the surviving payload; active defense of missile sites, land-mobile missiles and sea-based missiles. None of the Service studies addressed the question of active defense of missile sites and, consequently, it was omitted from this study. The land-mobile system presented by the Air Force study was not competitive with balanced proliferation. For some cases Soviet sea-based missiles are competitive. This is discussed further in the Anti-Submarine Warfare section.

Soviet adoption of balanced proliferation in order to optimize second-strike payload has the effect of reducing Soviet first-strike payload for a given budget. This is because smaller, less efficient missiles must be deployed.

The marginal cost of SOF is influenced by the (1) size of Soviet missiles (KP/site); (2) occupancy of Soviet missile sites when U.S.SOF arrives; and (3) the survivability of U.S. missiles.

For a fixed Soviet missile size one reliable U.S. re-entry vehicle (of high SSPK) per Soviet site is very competitive with other means of limiting damage while a second re-entry vehicle against the same target is not always competitive. In particular, a follow-on aircraft attack is competitive with a second re-entry vehicle under some circumstances.

For typical Soviet offensive force mixes U.S. Strategic Offensive Forces receive about 20% to 30% of the total U.S. Damage Limiting budget when the U.S. designs for Soviet second-strike counter-value.

Assured Destruction of the Soviet Union (or conversely: Damage Limiting for the Soviet Union)

The mirror image problem of damage limiting for the Soviet Union was analyzed, using the same techniques, on the basis of giving the Soviets the same state of technology and the same costs for comparable systems. Damage limiting was found more costly to the Soviets to achieve the same level of surviving population. A large part of this asymmetry stems from: (1) the fact that pre-FY 66 U.S. expenditures (sunk costs) provided forces useful in limiting damage to the U.S., whereas the best Soviet choices involved new systems; (2) the Soviets were not given an ASW capability; and (3) the geographical asymmetries of the two countries. (Against U.S. POLARIS submarines, and without a large ASW base to build on (sunk costs for U.S.), ASW would not be as attractive for the Soviets).

Soviet Civil Defense

A full fallout shelter program shows high utility for the Soviets -- this is especially true for reducing fatalities in their large dispersed rural population. Sufficient data was not available to examine the utility of blast shelters for the Soviet Union.

Soviet Ballistic Missile Defense

For 197x the Soviet was given credit for NIKE-X technology and a series of deployments based on U.S. costs and effectiveness were examined. These costs are $2.4 B plus $2 M per object shot down. In the context of assured destruction against this defense the U.S.

missiles used pure multiple warheads rather than decoys which might not work. Although the optimum multiple warhead size was found to depend upon the size of the Soviet Ballistic Missile Defense budget, a single design of 100 KT, 200 lb. warheads was used. This design is near-optimum over most of the range of Soviet deployments considered.

It is pertinent to examine the situation where the U.S. posture "assures" some level of destruction for the Soviet Union before the Soviets deploy a ballistic missile defense. If the Soviets now deployed a ballistic missile defense, the U.S. could maintain that level of damage by providing one kilopound of (surviving) payload for every $10 million the Soviets spend on a NIKE-X type system. This is on the basis that the U.S. utilizes five 200 lb., 100 KT R/Vs per kilopound of payload. In terms of "new buy" POLARIS (B-n) missiles, this would be a U.S. cost of about $7 million for every $10 million of Soviet expenditure on BMD. This assumes the U.S. attacks and destroys all defended cities -- as well as the undefended cities -- that were targeted before the Soviet BMD deployment. (A rank-order attack). Use of maximum fatality attacks and inclusion of other missile systems could reduce the ratio of U.S. to Soviet costs.

Soviet Strategic Offensive Forces

Soviet missiles are always applied to U.S. bomber bases and submarine ports and, for a small cost, destroy essentially all non-alert bombers and submarines there present. For Soviet designs for U.S. second-strike counter-value, Soviet missiles are always

[redacted]

applied against the large U.S. ICBMs -- TITAN and ICM. However, targeting of MINUTEMAN tends to be competitive with Soviet Ballistic Missile Defense only if the Soviets (a) are designing for a high % Soviet population surviving, and (b) can individually target a kilopound or less, with good kill probability, on each MINUTEMAN site. The Soviets always have an incentive to target enough U.S. ICBMs to raise the U.S. cost per surviving ICBM kilopound up to the corresponding cost for an alert kilopound of payload in POLARIS.

Soviet Bomber Defenses

Soviet Terminal Bomber Defenses were deployed similarly to the U.S. deployment: (a) a light cover of HAWK/HERCULES type defenses to deny serial bombing and force the use of Short Range Air-to-Surface Missiles (SRAM) and (b) interlocking, in cities defended against missiles, with AADS-70 type units whose technology is similar to NIKE-X. The cost for these units to shoot down a SRAM is about the same as for NIKE-X to shoot down a re-entry vehicle, namely $2 million. It is not clear whether the SRAM presented by the Air Force is the best that can be done against this type of terminal defense. That is, with "non-leaky" defenses that are postulated for AADS-70, the onus is on the offense to generate a larger number of SRAMs -- and thus a smaller SRAM -- even at the expense of yield.

Soviet Area Bomber Defense competed favorably with these terminal defenses against subsonic U.S. bombers but not against supersonic U.S. bombers.

[redacted]

Soviet Anti-Submarine Warfare

With the limited amount of data available, but given the characteristics of U.S. POLARIS submarines, and the fact that the Soviets have no large base of ASW forces to build on, ASW was not included as an attractive alternative to BMD for the Soviets.

Overall U.S. - Soviet Comparisons

In the analysis the results of damage limiting calculations could be aggregated, using the observation that the ratio of expenditures -- damage limiting by one side to damage creating by the other -- represents outcomes, in terms of percent surviving, over wide variations of the threat. For example, if the Soviets spend $10 billion to create damage, and the U.S. spends about $10 billion dollars to limit damage, a ratio of one-to-one, then the percent U.S. population surviving a Soviet second-strike is about 70-75%. This holds over a wide range of Soviet threats. If the Soviets spend at the same ratio, about 55% of the Soviet population would survive a U.S. second-strike.

The ratios, at a given "% Surviving", depend on (1) the situations for which each side designs; (2) the scenario -- e.g. first or second-strike counter-value campaigns, the occupancy of SOF targets; and (3) the relative composition (missiles, bombers, submarines) of damage creating forces.

Other aggregations are possible. The tables below show outcomes as a function of the ratio of the total amount the U.S. spends to limit damage and assure destruction to the amount the

[redacted]

Soviet spends for the same objectives. The fraction of the amount the Soviet spends to limit damage is held constant in each table. The percents surviving are second-strike counter-value outcomes as viewed by both sides.

$\frac{Lus + Cus}{Lsov + Csov}$ [1]	Outcome % U.S. Pop. Surv.	% Sov. Pop. Surv.
$\frac{Lsov}{Lsov + Csov} = .2$		
.5	50%	70%
.7	70%	70%
1.0	80%	70%
1.2	85%	70%
1.7 (approx)	90%	70%
$\frac{Lsov}{Lsov + Csov} = .6$		
.4	60%	70%
.5	70%	70%
.7	80%	70%
.8	85%	70%
1.0 (approx)	90%	70%

1/ Lus (Lsov) is \$ U.S. (Sov) spends on damage limiting
Cus (Csov) is \$ U.S. (Sov) spends on damage creating

[redacted]

B

L

A

N

K

Appendix

Kilopounds As A Measure of Effectiveness

Throughout the study the common denominator of comparison between damage limiting forces was the cost to offset or negate the effects of a kilopound of missile payload. To see how this is a valid and useful method of comparison consider the following:

The probability of a point target surviving a single shot attack by a warhead with a lethal radius of L feet is given by

$ssP_s = (.5)^{\frac{L^2}{CEP^2}}$ where CEP expresses the expected accuracy of delivery. The probability of surviving n identical, independent attacks is then given by $P_s = (ssP_s)^n = (.5)^{\frac{nL^2}{CEP^2}}$. An analysis of nuclear weapons effects shows, to a good approximation, that the lethal radius for blast damage, L, is related to the warhead yield, Y, by $L = k\,Y^{1/3}$, where k expresses the hardness or vulnerability of the target. Combining this expression for L and P_s we obtain

$$P_s = (.5)^{\left(\frac{k}{CEP}\right)^2 n\,Y^{2/3}}$$

. Thus for a given hardness, k, and delivery accuracy, CEP, the probability of survival, P_s, depends upon the parameter, $n\,Y^{2/3}$.

For attacks on area targets the lethal area covered by a single warhead is proportional to L^2 so that the area covered by n warheads is proportional to $n\,Y^{2/3}$. Comparisons of detailed damage runs against population distributions verify that $n\ Y^{2/3}$ is a good measure of damage so long as the yields are small enough so that the lethal radius, L, is small compared with the radius of the individual cities.

A comparison of nuclear warhead yield and weight over a range of yields (for a fixed warhead technology) shows that the total weight of n re-entry vehicles having warheads of yield, Y, is, to a good approximation for yields above 100 KT, also proportional to $n\ Y^{2/3}$. Thus the damage created by n warheads of yield Y is determined by $n\ Y^{2/3}$ which in turn is proportional to the total weight of the warheads.

If yields below a few hundred KT are used then the relationship does not hold exactly. In this study the reduced damage potential of small warheads was taken into account. Payload used for decoys, rocket motors and other penetration aids was also taken into account.

Bomber payload can be equated to missile payload on the basis of the damage that can be inflicted. Alternatively, one can equate bomber payload to missile payload on the basis of the missile payload needed to deliver the same number of warheads of the same yield. Because the missile payload is a good measure of missile damage potential it follows that the same bomber to missile equivalence is reached on either basis.

If two delivery systems, A and B, have different delivery accuracies, then the above relationships show that the payload of system A to do a given job is related to the payload of system B to do the same job by Payload A $= \frac{(\text{CEP for A})^2}{(\text{CEP for B})^2}$ Payload B

For this study all systems that were compared on a payload basis were attributed comparable CEPs for the time period 197x.