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-- DAMAGE LIMITING --

A RATIONALE FOR THE ALLOCATION OF RESOURCES

BY THE US AND THE USSR

Prepared for

The Director of Defense Research and Engineering

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GENERAL OUTLINE OF STUDY

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INTRODUCTION

This analysis examines the relative merits in a 1970 time frame of four means of limiting damage to population and industry: (1) Civil Defense -- to decrease the vulnerability of the population; (2) Ballistic Missile Defense interlocked with (3) Terminal Bomber Defense -- to destroy weapons enroute to target as well as make high worth defended targets unattractive to attack; and (4) Strategic Offensive Forces -- to destroy enemy weapons before launch. Decreasing returns to scale operate for each of the four separately which suggests analyzing their effects in combination.

The study is carried on in parametric fashion with emphasis throughout on optimum solutions (i.e., given % Surviving for least cost or greatest possible % Surviving for a given cost). Behavior around optima is also traced. The analysis involves sub-optimizing facets of each of the four means of damage limiting before the progressive optimization of Civil Defense with Ballistic Missile Defense and Terminal Bomber Defense, the latter two appropriately interlocked; then all three with Strategic Offensive Forces. As may be seen from the outline on page 1, the optimization among these means progresses in parallel fashion for both the U. S. and the Soviet Union, culminating in parametric comparisons of defense/offense cost ratios and overall effects of damage limiting in both countries under various scenarios.

Throughout the study, unless otherwise stated, urban/industrial damage for both the U. S. and U. S. S. R. includes collateral effects from a 5000 megaton concurrent attack on military targets. Missile reprogramming capability for reliability is assumed for both sides. High confidence attacks are considered, with emphasis upon blast (and fallout) as damage agents. Blast is the most prominent means of inflicting damage (this is particularly true if fallout protection is provided); measures of lower confidence -- such as high altitude detonations to enhance thermal effects -- are not addressed here. The study concentrates on relationships and planning and does not include the full variety of possible weapon systems available in the future and how they may be related to the variables used here.

The analysis begins, for each country, with damage curves (% Surviving vs. Number of Attacking Missiles) for selected Civil Defense postures. Next, Ballistic Missile Defense is considered, and optimal combinations of radars and interceptors are found. To prevent bombers from circumventing Ballistic Missile Defense, a Terminal Bomber Defense is included at all missile-defended targets. (Data and time limitations prevented the consideration of interlocked Terminal Bomber Defense for the Soviet Union.) The sub-optimization of Terminal Bomber Defense necessitated analysis of area bomber defense, but only calculations pertaining to the terminal region are included here. Then, Civil Defense and Ballistic Missile Defense/Terminal Bomber Defense are considered together -- to optimize Terminal Defense overall. Even with optimized Terminal Defense, however, it remains difficult to negate the effects of large attacks on urban/industrial areas. This leads to a consideration of the utility of reducing the size of the attack by destroying enemy missiles -- by means of Strategic Offensive Forces -- before they are launched against cities.

Comparisons are made of defense/offense cost ratios for the two countries in considering the economic competition involved in defense/offense reactions. Finally, damage to both countries is described under various scenarios. These, together with considerations of the relative levels of effort of the two countries -- levels of effort with regard to resources that may be applied to both offense and defense -- provide estimates of the range or "ball park" of the potential damage to each.

The main development of the analysis is presented in a series of 29 graphs. Each graph is accompanied by a plate of conditions and assumptions that apply to the graph. Further, each plate contains a list of basic observations regarding the behavior of the variables considered in the graph. Main attention is given to the optimum points shown on the graphs, but since curves trace out many possible solutions, this graphical, parametric means of analysis is able to consider the behavior of the phenomena under study. Thus, an important reason for presenting the analysis in the series of graphs is their capability of showing behavior around optimum solutions, without being forced to accept discrete points as final solutions. It is particularly important to note that the purpose of the study is to examine general behavior to provide an overall framework. The study is not to be considered as an exhaustive analysis of any particular component. For example, a fairly simplified model for NIKE-X is used. One would expect that the more exhaustive study now being conducted by the Army will provide more insight into this particular facet of the overall problem. Also this study should not be considered as the last word on the utility of blast shelters.

The analysis is followed by a summary of general observations on the subject of damage limiting.

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FIGURE 1

% U. S. POPULATION AND MANUFACTURING VALUE ADDED (MVA) SURVIVING vs NUMBER OF RELIABLE SOVIET MISSILES ATTACKING U. S. CITIES FOR VARIOUS CIVIL DEFENSE (CD) POSTURES

Time Frame 1970 -- For the entire analysis. Total population is 210 million.

Attack -- Soviets attack MVA targets in order of worth destroyed per missile.

Soviet missile has 5 MT Equivalent, — S-RD with yield ⇒ level of worked technology payload, surface burst with 1 n.mi. CEP. (Soviet SS-7).

Percent population surviving is shown by solid lines.

Percent MVA surviving is shown by dotted line.

Collateral Damage (Shown by less than 100% surviving for zero missiles attacking cities) is from 5000 MT delivered on U. S. military targets.

Civil Defense Postures

Curve	CD Posture	Cost ($ Billions)*	Blast Criteria	Radiation PF**	Description
A	Nr 1	$0	6.5 psi	4.2	Existing posture.
B	Nr 2	$0.07	6.5 psi	10	70 million spaces (Fallout Shelters)
C	Nr 6	$5.8	6.5 psi	35.7	230 million spaces (Fallout Shelters)
D	Nr 8	$16.2	30/10/6.5 psi	35.7	***Fallout + Blast 30 psi-34 million spaces 10 psi-42 million spaces
E	Nr 9	$22.4	30/10/6.5 psi	35.7	***Fallout + Blast 30 psi-55 million spaces 10 psi-70 million spaces

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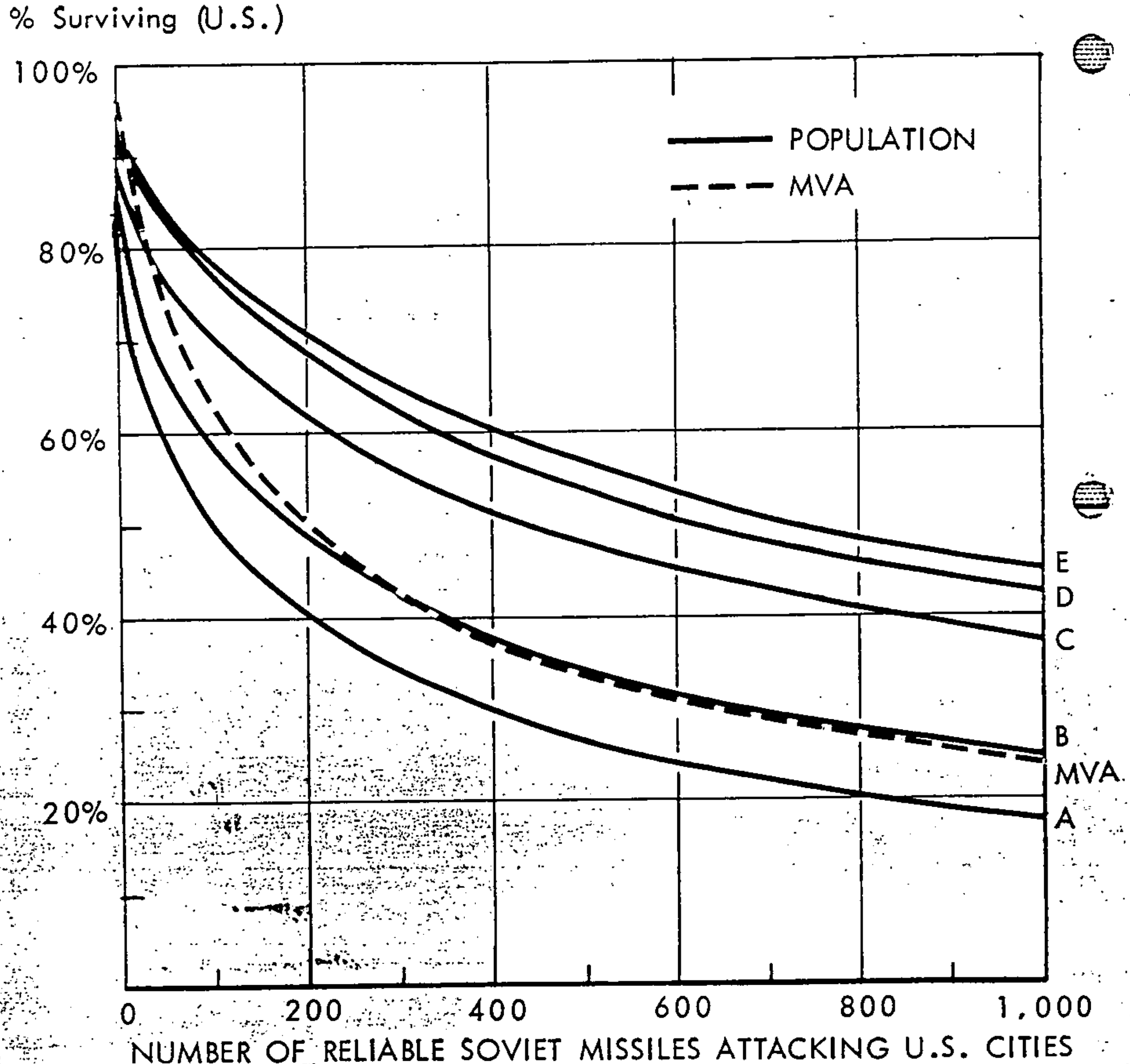
Figure 1

% U.S. Pop./MVA Surviving vs Number of Reliable Soviet Missiles Attacking U.S. Cities for Various Civil Defense (CD) Postures

(ATTACK ON MVA)



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Shelter effects are degraded for the 10% of the population that do not occupy the best available shelters and for post-attack effects (lifetime dose).

* Costs are total investment costs.

** PF means "Protection Factor".

*** Blast shelter programs involve 30 psi shelters in central city areas and 10 psi in suburbs. Posture Nr 8 has a blast shelter program for the 22 largest Standard Metropolitan Statistical Areas and Nr 9 for the 100 largest.

Basic Points

(1) Full fallout shelter program (Line C) saves approximately 20% more of the population, for all sizeable Soviet attacks, than no civil defense program (Line A).

(2) CD gets increasingly expensive per life saved at higher levels of population surviving. E.g. for 400 missiles attacking:

% Surviving Population	Cost ($ Billions)	Approx. Cost/% Saved ($ Billions)
30%	0	0
38%	$.07 B	$.01 B
52%	$5.8 B	$.26 B
58%	$16.2 B	$.58 B
60%	$22.4 B	$.75 B

(3) CD, of course, does not protect U. S. MVA.

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FIGURE 2

% U. S. MVA SURVIVING vs COST BALLISTIC MISSILE DEFENSE (BMD) FOR SELECTED NUMBERS OF ATTACKING MISSILES

Attack

(1) [redacted] payload against defended targets (Equivalent of 5 MT + 10 objects) ("SS-8" or "SS-X-1").

(2) [redacted] payload against undefended targets (Equivalent of 5 MT) (SS-7).

(3) (Above missile threats from DDR&E "ICBM Threat Analysis -- Re-entry Systems" 18 September 1963).

(3) Attacker given full knowledge of defenses and has option, for maximum kill, to attack defenses or avoid them.

(4) No collateral damage from military attacks is included here (and on Figure 3) -- design for defenses uses values of intact targets.

BMD Defense

(1) NIKE-X System. $SSP_k = 0.8$ for a single interceptor against an object. (Re-programming of interceptors for early aborts is not considered).

Central radar and associated installation costs $400 million.

Interceptors cost $1.25 million each including warhead and associated equipment.

(All 5-year system costs).

(2) Each defense unit provides an "Effective Exclusion Radius" of

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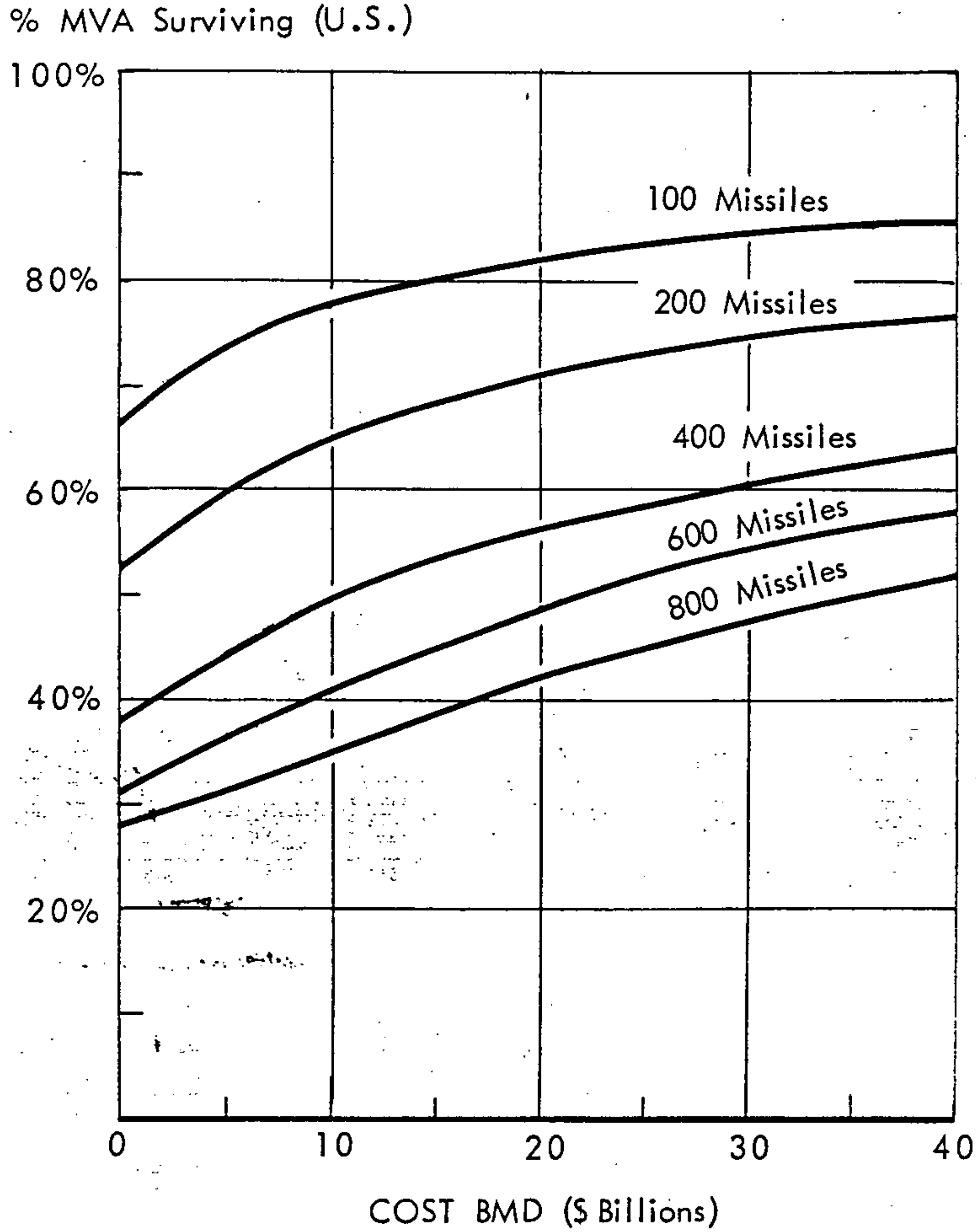
Figure 2

% U. S. MVA Surviving vs Cost Ballistic Missile Defense (BMD) for Selected Numbers of Attacking Missiles



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10 n.mi. Defense units are deployed at each aim point (determined in the undefended case). Possible economies in radars covering adjacent exclusion areas are not treated here.

(3) Firing doctrine for interceptors: Prim-Read strategy.

(4) Ratio of interceptors/radar is optimum for each size of attack and for each size of BMD program.

(5) Final design -- used following Figure 3 -- is for 400 missile attack. That design involves a ratio of interceptors/radars which tends to minimize effects of design not being optimum for other sizes of attack.

Basic Points

(1) Greater investment in BMD saves more MVA at slowly diminishing marginal returns.

(2) Slopes of curves in Figure 2 are fairly insensitive to size of attack -- value for additional dollar spent is roughly constant for all sizes of attack.

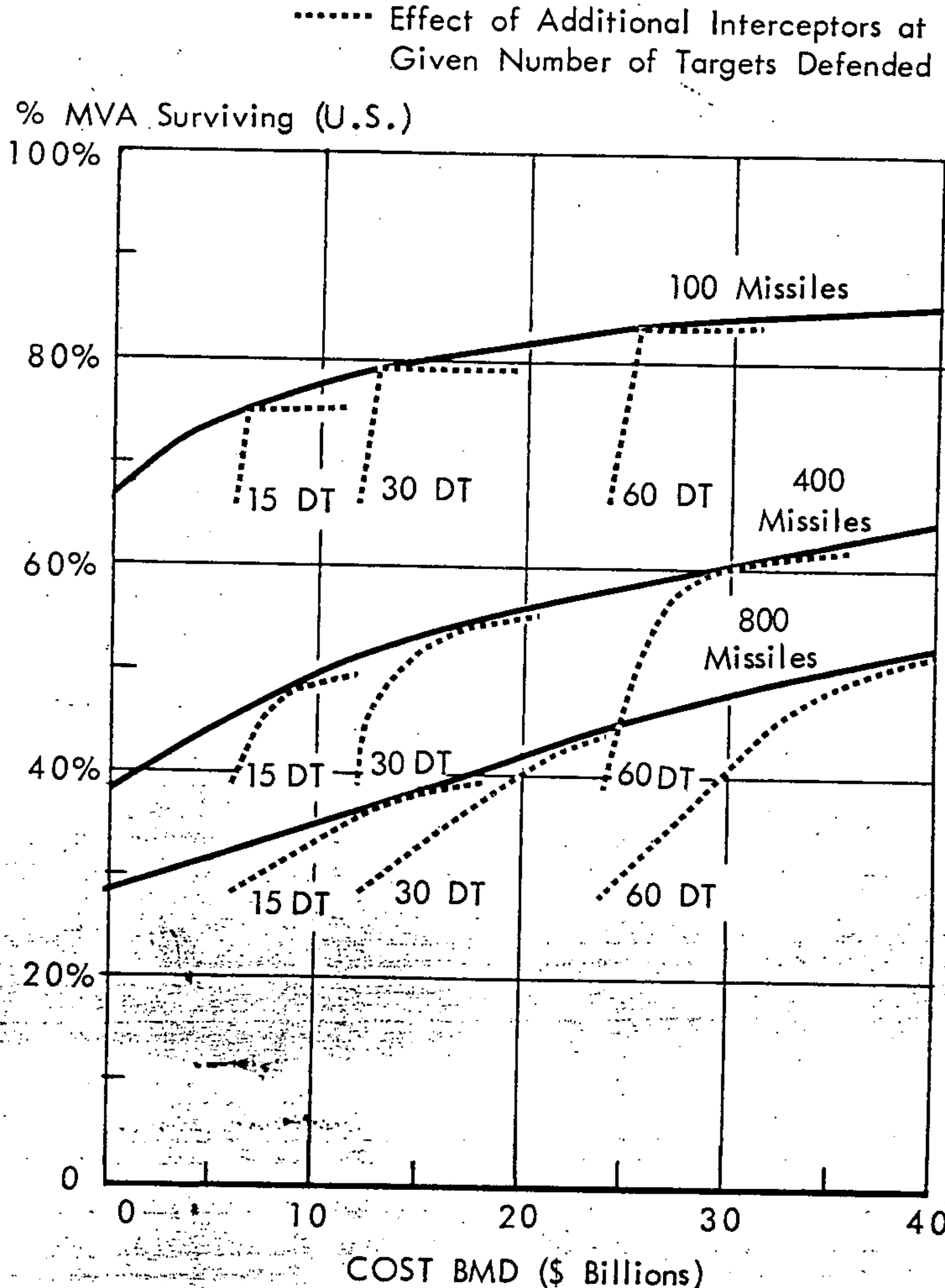
(3) A characteristic of the BMD design is that the attacker's best option (in getting most overall damage) is to avoid the defenses and attack undefended targets, until the expected damage/missile in the undefended region is less than the expected damage/missile against higher worth defended targets. The expected damage/missile in the defended area is constant for all defended targets and all missiles attacking -- a characteristic of the Prim-Read strategy. Thus the effect of BMD is to rerank the

order of attack, putting the highest worth defended targets after a large number of undefended ones.

(4) Other calculations, not shown here, indicate that saturation effects on BMD do not change the optimization of a deployed system. Saturation, in this context, can be viewed as an upper limit to the price that the defense can charge for a target.

Figure 3

% U. S. MVA Surviving vs Cost BMD for Selected Numbers of Attacking Missiles



Note: DT means Defended Targets.

FIGURE 3

% U. S. MVA SURVIVING vs COST BMD FOR SELECTED NUMBERS OF ATTACKING MISSILES

Repeat of 100, 400, and 800 missile attacks of Figure 2, Showing Effects of Adding Interceptors to a Given Number of Defended Targets (Dashed Lines).

(1) The dashed lines show the effect of deploying interceptors for a given number of radars. The number of interceptors can be found by taking the cost increment for interceptors and dividing by $1.25 million (cost per interceptor). E.g.: for 400 missile attack, 30 targets defended, the "interceptor curve" is tangent to the envelope at a total cost of $16.9 billion -- $12.0 billion of this is on radars (30 targets defended). This leaves $4.9 billion on interceptors. This buys about 3900 interceptors.

(2) Solid lines (envelopes of dashed curves) show best mix between numbers of interceptors and numbers of radars for a given size attack.

(3) Mixture of radars and interceptors is a function of size of attack. Optimum mixture for larger attacks requires more interceptors per radar. Thus at a given total cost, optimum design is to defend fewer target areas, but with more interceptors, as attack size increases.

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Figure 4

Cost Terminal Bomber Defense (TBD) vs Cost BMD

(Balanced Interlocking Defense)

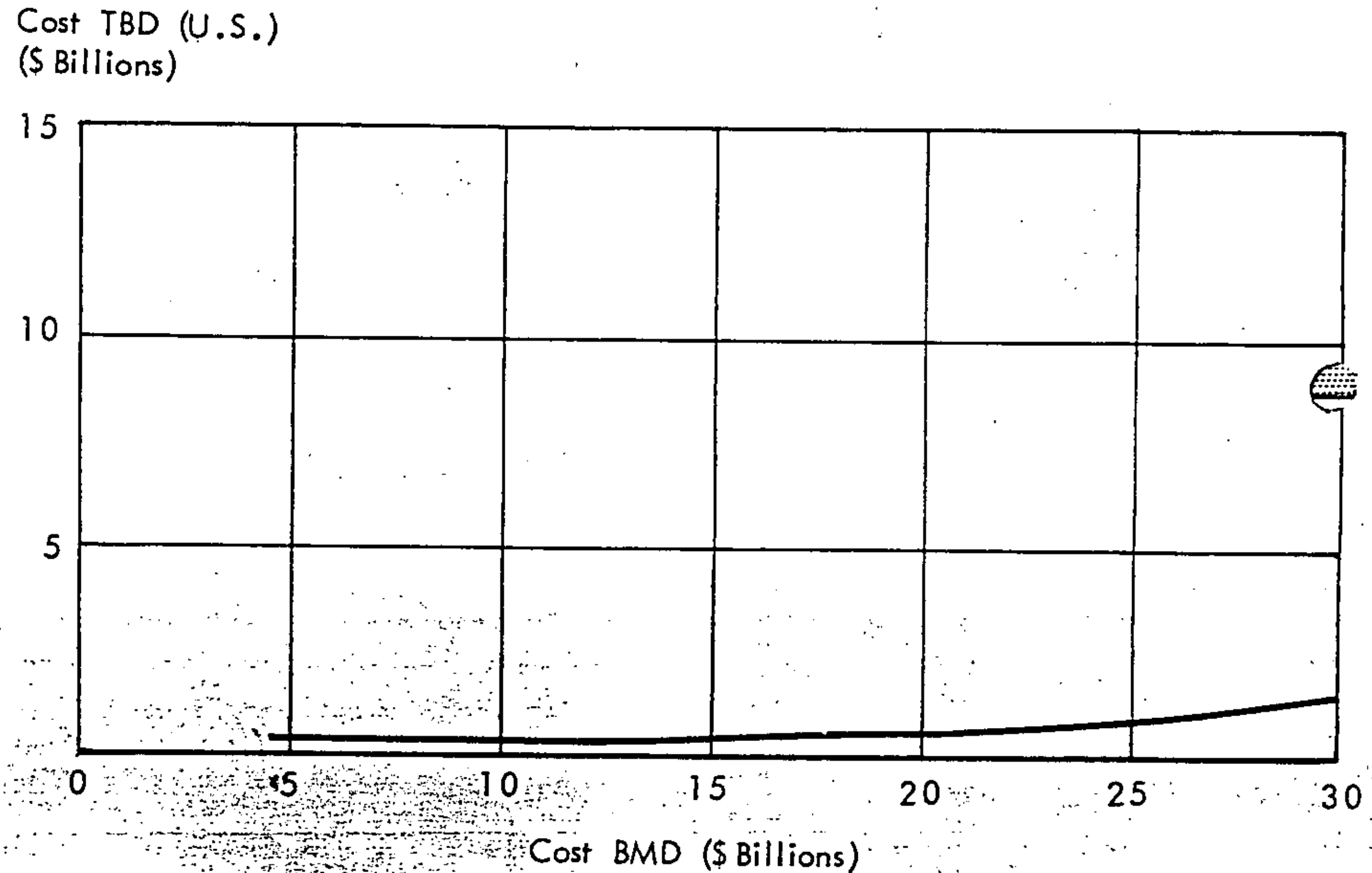

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FIGURE 4

COST TERMINAL BOMBER DEFENSE (TBD) vs COST BMD (U. S.)

Attack

Soviet bombers assumed to have capability of dropping up to four 8 MT bombs at a target. This means that each bomber has a "city buster" capability for all but the largest cities -- essentially 100% destruction of MVA of smaller cities by one aircraft.

Defense

(1) System considered is the Hawk system deployed at targets defended by BMD. System deployed under BMD "umbrella" for interlocking defense. Other systems (area defense, NIKE-HERCULES) are not included -- they are assumed to act on penetration probability, P_A, to the terminal area. Hawk system $SSP_k = 0.8$ for a single interceptor against an aircraft. Five-year-system-cost $5.2 million/fire unit.

(2) System deployment designed against low altitude saturation attack (will work better vs non-saturation attacks).

(3) Design is for "Balanced Defense". Deployment of TBD is such that Soviets will always find it their best option to use bombers against undefended targets. (This deployment is independent of area penetration probability of bombers).

Basic Points

Cost of TBD system interlocked with BMD is very small fraction of the BMD expenditure and changes slowly with amount spent on BMD.

Figure 5

% Surviving (U.S. Pop. & MVA) vs Cost BMD/TBD for Selected Total Terminal Defense (TD) Costs

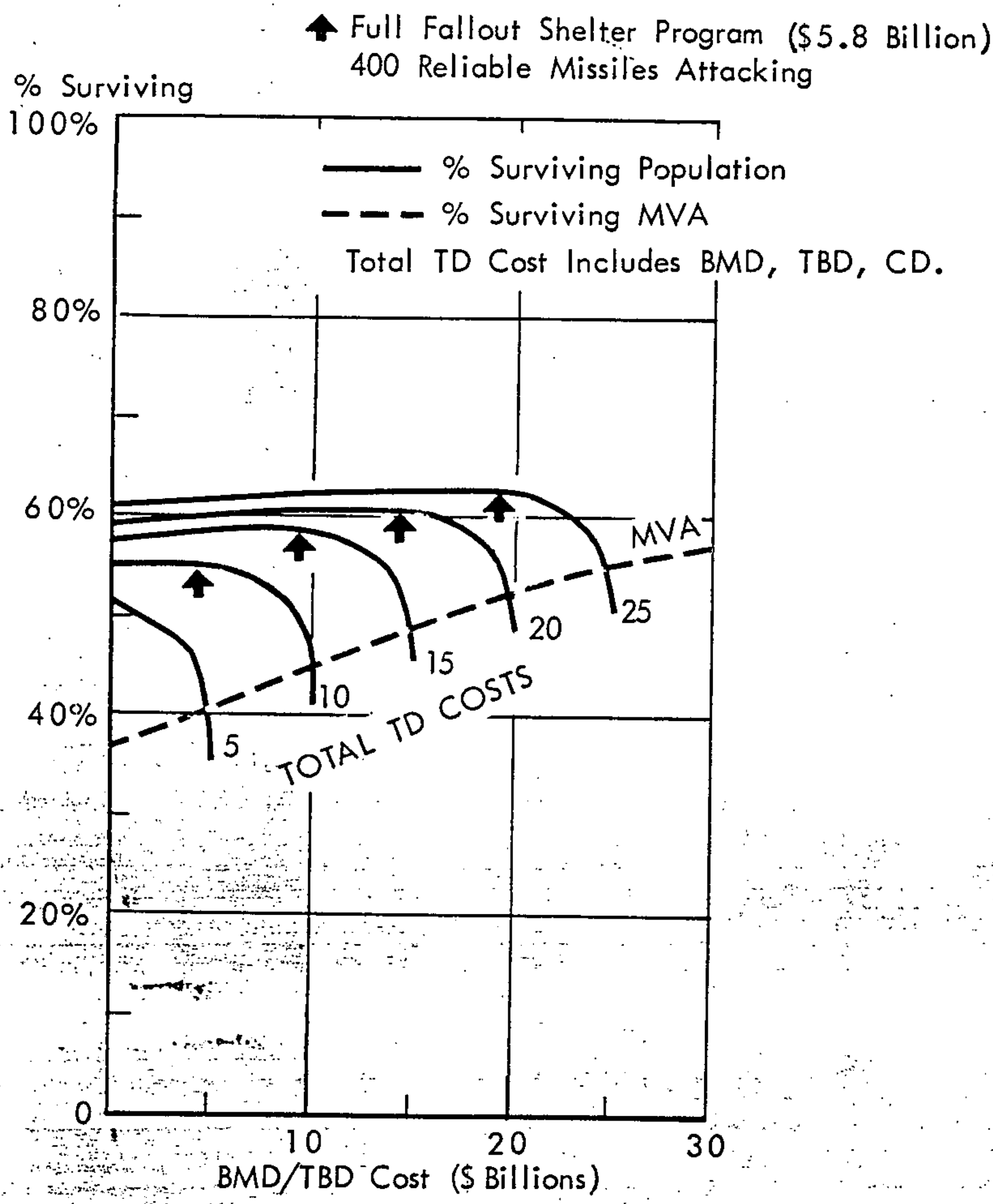

FIGURE 5

% SURVIVING U. S. POPULATION AND MVA vs COST BMD/TBD FOR SELECTED TOTAL TERMINAL DEFENSE (TD) COSTS (TD INCLUDES BMD, CD, TBD)

Attack

400 reliable missiles attacking U. S. cities.

5000 MT on military targets.

CD: Data from Figure 1.

BMD: Effectiveness and cost from Figure 2 -- design is for MVA defense for 400 missile attack.

TBD: Costs from Figure 4.

Arrows indicate points on population curves corresponding to allocations for full fallout shelter program. These arrows are $5.8 billion to the left of the total amount of money. (TD Costs).

Basic Points

(1) For total budgets larger than that necessary for the full fallout program ($5.8 billion) there is no essential difference in terms of lives saved whether money is allocated to CD (blast shelters) or to BMD. But, BMD would be the better investment since it also acts to save industry -- and at virtually no cost in terms of population saved.

TBD

(2) If all the money is allocated to BMD/[redacted] -- none to CD -- there is a small increase in the "% MVA Surviving" -- as shown by the slope of dotted line -- but a very significant decrease in "% Population Surviving" -- as shown by rapid drop off of solid lines.

(3) Results above hold for other sizes of attack (not given here).

(4) Subsequent calculations will thus be done on the basis that the first $5.8 billions are spent for a full fallout shelter program, and additional expenditures are made for BMD/TBD.

(5) With the full fallout shelter program, calculations (not given here) show that BMD deployment optimized to protect MVA, is also very nearly optimum deployment for population defense.

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Figure 6

% Surviving (U.S. Pop. & MVA) vs BMD/TBD Cost for Selected Total TD Costs Showing Effects of TBD

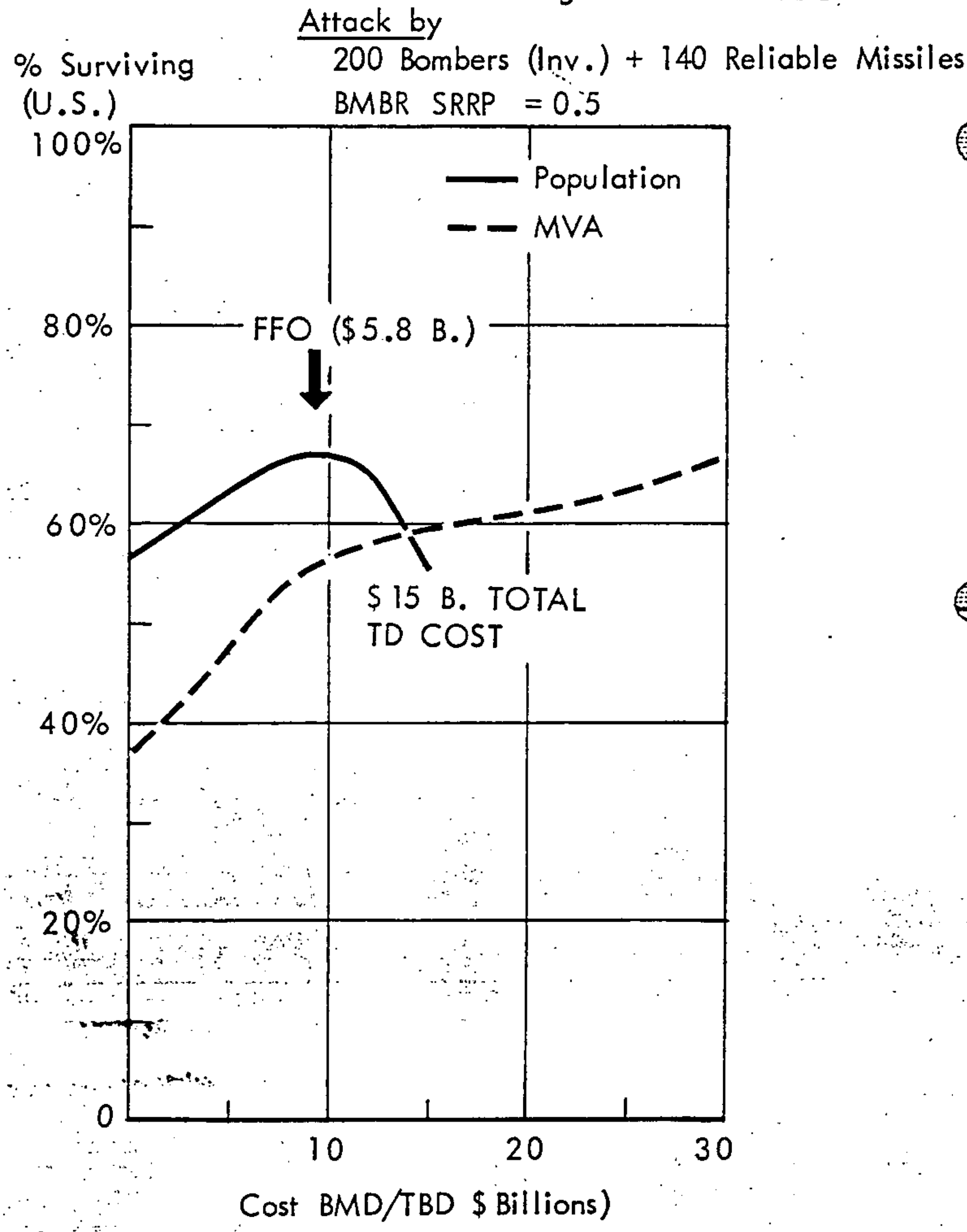

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FIGURE 6

% SURVIVING U. S. POPULATION AND MVA vs BMD/TBD COST FOR SELECTED TOTAL COSTS -- SHOWING EFFECTS OF TBD

Note

Figure 5 showed the relative utility of CD and BMD/TBD for a "pure" missile attack on U/I targets. This Figure repeats the analysis for a combined bomber/missile attack to show:

(1) The effect of the small added investment for interlocking BMD/TBD.

(2) Whether CD/BMD/TBD optimization is changed by the influence of bombers.

Attack

Attack size and mixture chosen to give same damage as 400 reliable missiles for no defense case.

This equivalent attack is taken to be 200 Soviet bombers (inventory) and 140 reliable Soviet missiles. Bomber survivability X readiness X reliability X area penetration probability ($SRRP_A$) = 0.5. This factor is taken into account in attack programming.

Defense

BMD/TBD coupling and assumptions from Figure 4. Figure 5 included TBD costs but showed a pure missile attack. This figure shows the effect of that small added expenditure for a mixed attack of bombers and missiles.

Basic Points

(1) Large increases in "% Surviving" are possible by interlocked BMD/TBD defenses. (comparing Graphs 5 and 6). If BMD and TBD were not interlocked, either measure alone would have no utility in this case -- bombers would destroy targets that are defended by BMD only and missiles would destroy those targets defended by TBD only.

(2) There is a large increase in population surviving (at a small loss of MVA) by spending $5.8 billion for a full fallout shelter program instead of spending all $15 billion on BMD/TBD. This is the same behavior as in the previous Figure. Full fallout shelters are still the best initial investment for saving lives. This is shown by the fact that there is a maximum at the point where $5.8 billion (full fallout shelter) is allocated to CD. To the left of that point there is increasingly more allocation to CD but at the expense of decreases in both population and MVA surviving.

(3) BMD/TBD now looks better than blast shelters in saving lives and has larger effect in saving MVA than in the pure missile attack of Figure 5.

(4) Note that for a terminal defense where BMD/TBD are interlocked, a pure U/I missile attack (no bombers) is the attacker's best option given the same total damage for all mixtures in the undefended case. (This can be seen by comparing this Figure

with Figure 5 (pure missile attack). The damage for no defense was the same for both cases -- 400 missiles in Figure 5 and 200 bombers plus 140 missiles in Figure 6. But when interlocked defense is introduced, "% Surviving" is greater for the mixed bomber-missile attack. It is 67% at an expenditure of $15 billion for TD (Figure 6) as compared with a maximum of 59% in Figure 5 for a pure missile attack.

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Figure 7

% Surviving U.S. MVA vs Number of Reliable Soviet Missiles Attacking U.S. Cities for Various Levels of TD Expenditure

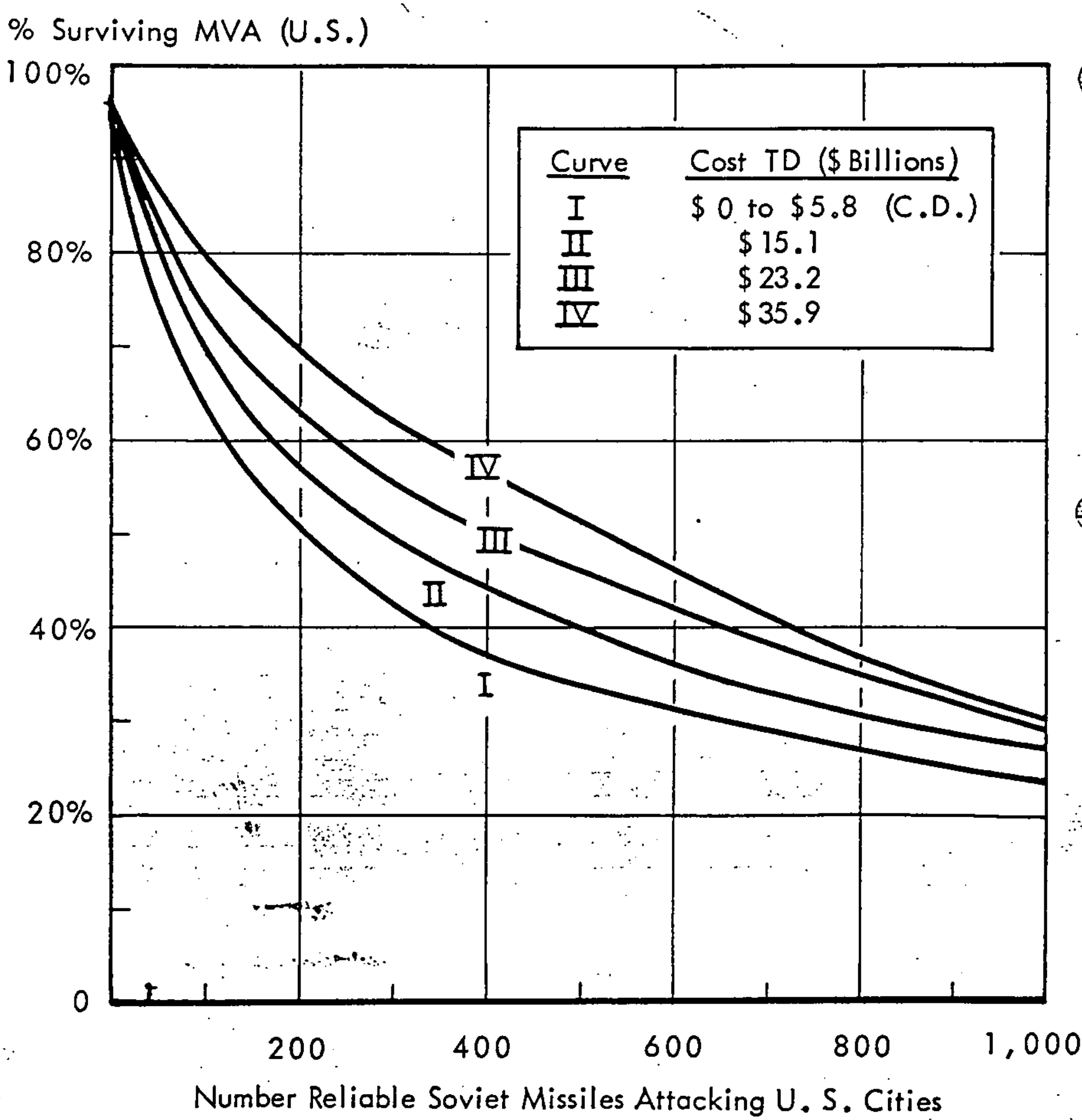

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FIGURE 7

% SURVIVING U. S. MVA vs NUMBER OF RELIABLE SOVIET MISSILES ATTACKING U. S. CITIES FOR VARIOUS LEVELS OF TERMINAL DEFENSE (TD) EXPENDITURE

Curve	Cost	Description
I	$0 to $5.8 B	Population protection only. No ballistic missile defense (BMD/TBD) up to full fallout shelter program (FFO). (No difference to MVA).
II	$15.1 B	FFO plus 15 target areas defended by BMD/TBD.
III	$23.2 B	FFO plus 30 target areas defended.
IV	$35.9 B	FFO plus 60 target areas defended.

Basic Points

Increased expenditures on BMD/TBD result in a larger requirement for missiles to get a given "% Surviving MVA" or result in greater "% Surviving MVA" for a given size attack.

Cost TD	Example 1 Number Reliable Missiles Required to Get 50% Surviving	Example 2 % Surviving MVA for 400 missile attack
0-$5.8 B	210	37%
$15.1 B	300	45%
$23.2 B	410	50%
$35.9 B	530	57%

Figure 7A

% SURVIVING U.S. MVA vs NUMBER OF RELIABLE SOVIET MISSILES ATTACKING U.S. CITIES FOR VARIOUS LEVELS OF TD EXPENDITURE

Showing Maximum Effect of BMD

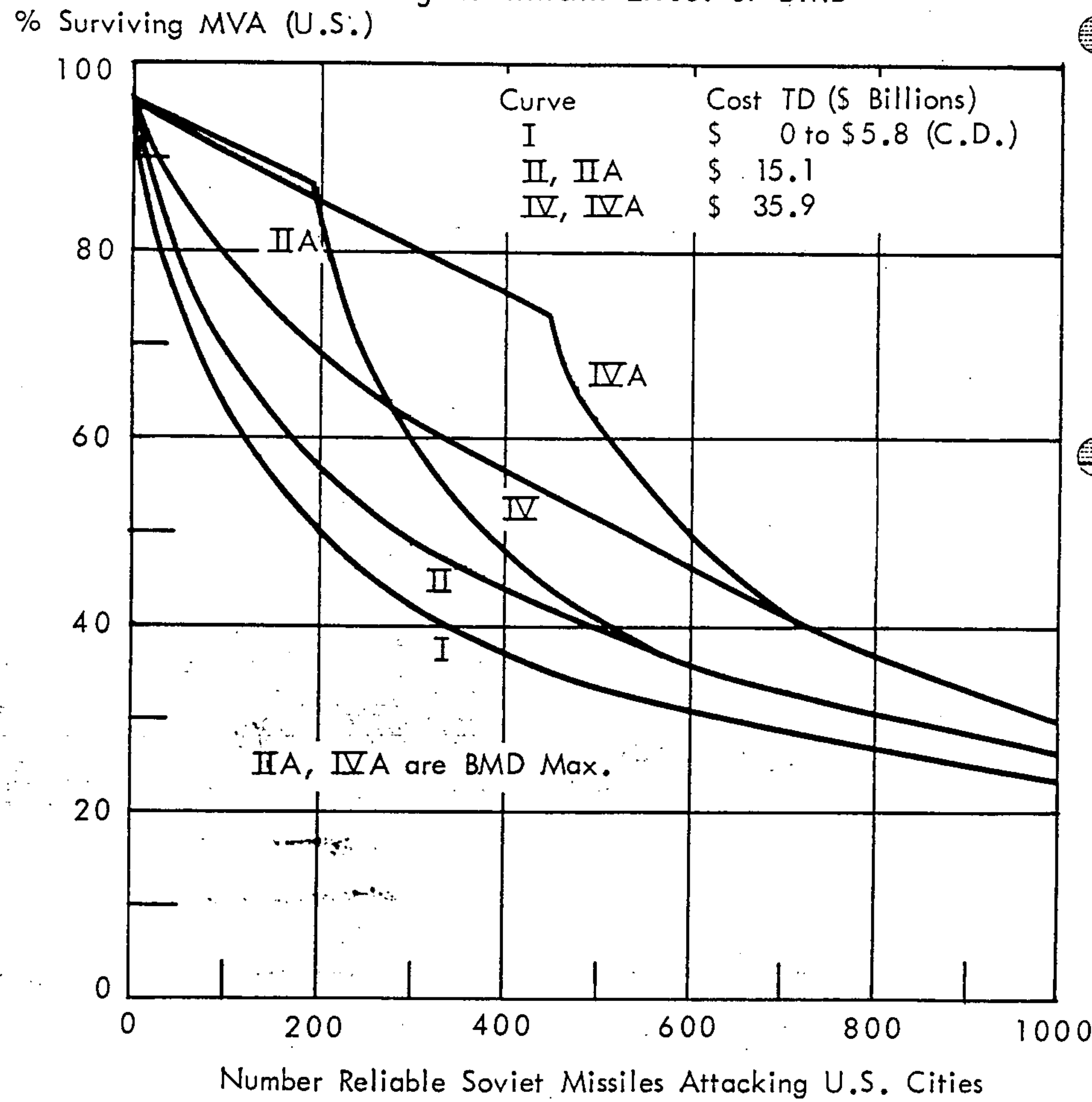

FIGURE 7 A

% SURVIVING U. S. MVA vs NUMBER OF RELIABLE SOVIET MISSILES ATTACKING U. S. CITIES FOR VARIOUS LEVELS OF TERMINAL DEFENSE (TD) EXPENDITURE

-- SHOWING MAXIMUM EFFECT OF BMD --

Same as Figure 7 except Curves II A and IV A are added to show a possible maximum effect of BMD. Maximum effect occurs when Soviets attack targets in order of worth -- paying the price for each defended area -- before attacking the undefended area.

Note: Total TD of $15.1 billion is allocated as follows: $5.8 billion for CD; $8.8 billion for BMD; and $0.5 billion for TBD.

$35.9 billion is allocated as follows: $5.8 billion for CD; $28.6 billion for BMD; and $1.5 billion for TBD.

Basic Points

(1) For small to moderate size attacks this Soviet strategy would result in up to an additional 28% or a total saving of up to 35% MVA for a TD investment of $15.1 billion (Curve II A). For a larger expenditure, $35.9 billion (Curve IV A) up to an additional 20% would be saved over the best Soviet strategy or a total of 38% MVA saved over the undefended case.

(2) Thus due to either (a) poor Soviet attack planning, or (b) unwillingness of the Soviets to attack lower worth undefended targets, leaving high worth targets in major cities intact,

the effect of BMD could be much larger than is shown in Figure 7. This holds for attacks of up to 200 to 400 missiles. The real case may be somewhere between the two limits discussed in paragraph 1 above.

(3) Despite the fact that U. S. damage might be considerably less with poor Soviet attack planning, the subsequent analysis, unless otherwise specified, assumes good attack planning on the part of the Soviets. In the final scenarios (Figure 27 and 28) this factor will be included to show the range of possible results.

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Figure 8

% Surviving U. S. Pop. vs Number of Reliable Soviet Missiles Attacking U. S. Cities for Selected Total Expenditures on TD

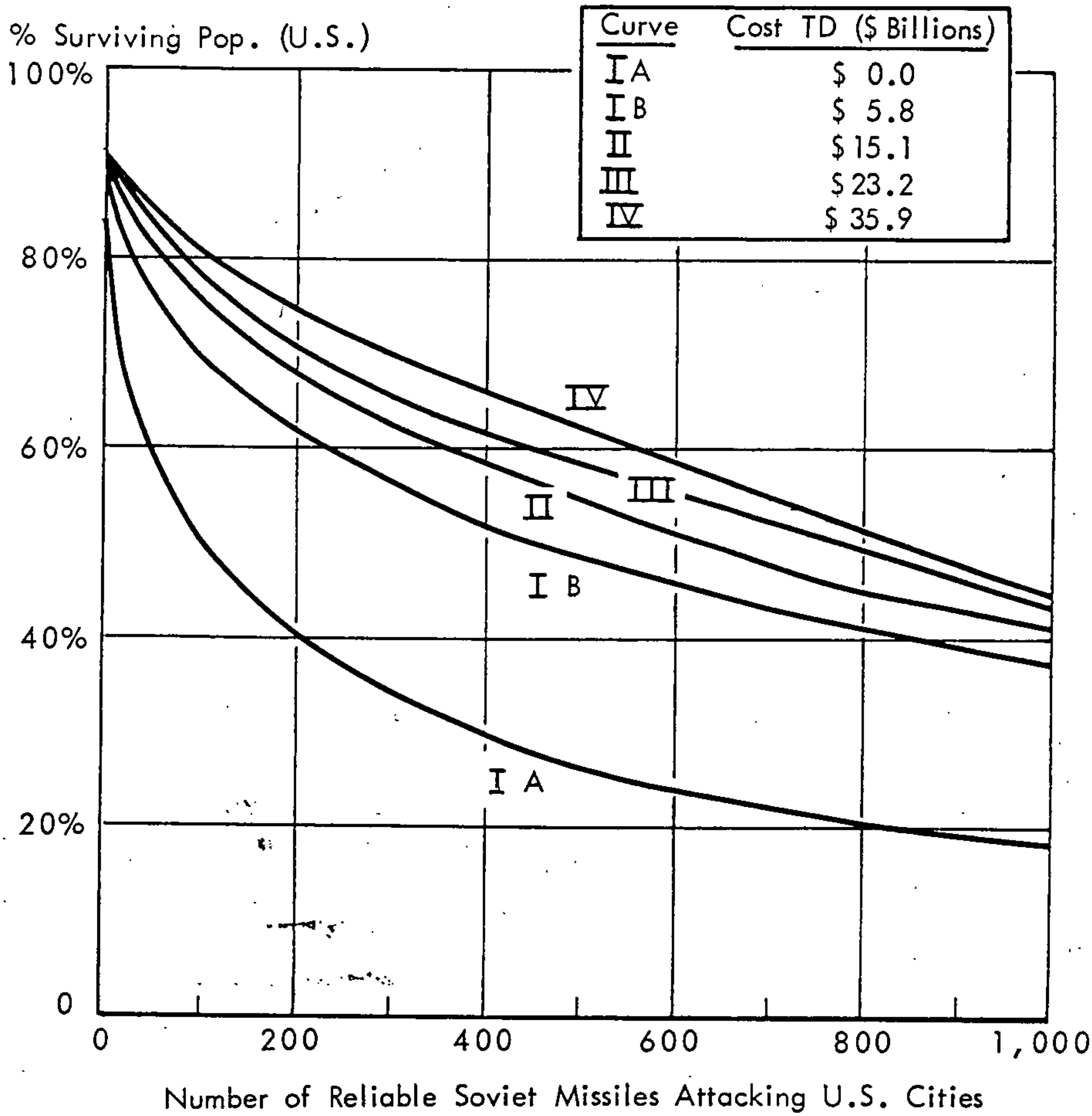

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FIGURE 8

% SURVIVING U. S. POPULATION vs NUMBER OF RELIABLE SOVIET MISSILES ATTACKING U. S. CITIES FOR SELECTED TOTAL EXPENDITURES ON TD

Repeat of Figure 7 but for population, showing large effect of full fallout shelter program.

Curve	Description
I A	No CD.
I B	Full fallout shelter program (FFO).
II	FFO + 15 target areas defended.
III	FFO + 30 target areas defended.
IV	FFO + 60 target areas defended.

Notes

(1) Attack is on MVA. BMD/TBD design is optimum for defense of MVA (but is also nearly optimum for population).

(2) BMD system is designed for 400 missiles attacking (described on Figure 2).

Basic Points

(1) The curves show that the initial investment in CD of $5.8 billion provides the largest return.

(2) More TD requires more attacking missiles for a given "% Surviving Population", or results in greater "% Surviving" for a given attack.

Cost TD	Example 1 Number Reliable Missiles Required to Get 50% Surviving	Example 2 % Surviving Population for 400 missile attack
0	100	30%
$5.8 B	450	52%
$15.1 B	620	58%
$23.2 B	770	62%
$35.9 B	830	66%

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Figure 8A

% SURVIVING U.S. POPULATION vs NUMBER OF RELIABLE SOVIET MISSILES ATTACKING U.S. CITIES FOR SELECTED TOTAL EXPENDITURES ON TD
Showing Maximum Effect of BMD

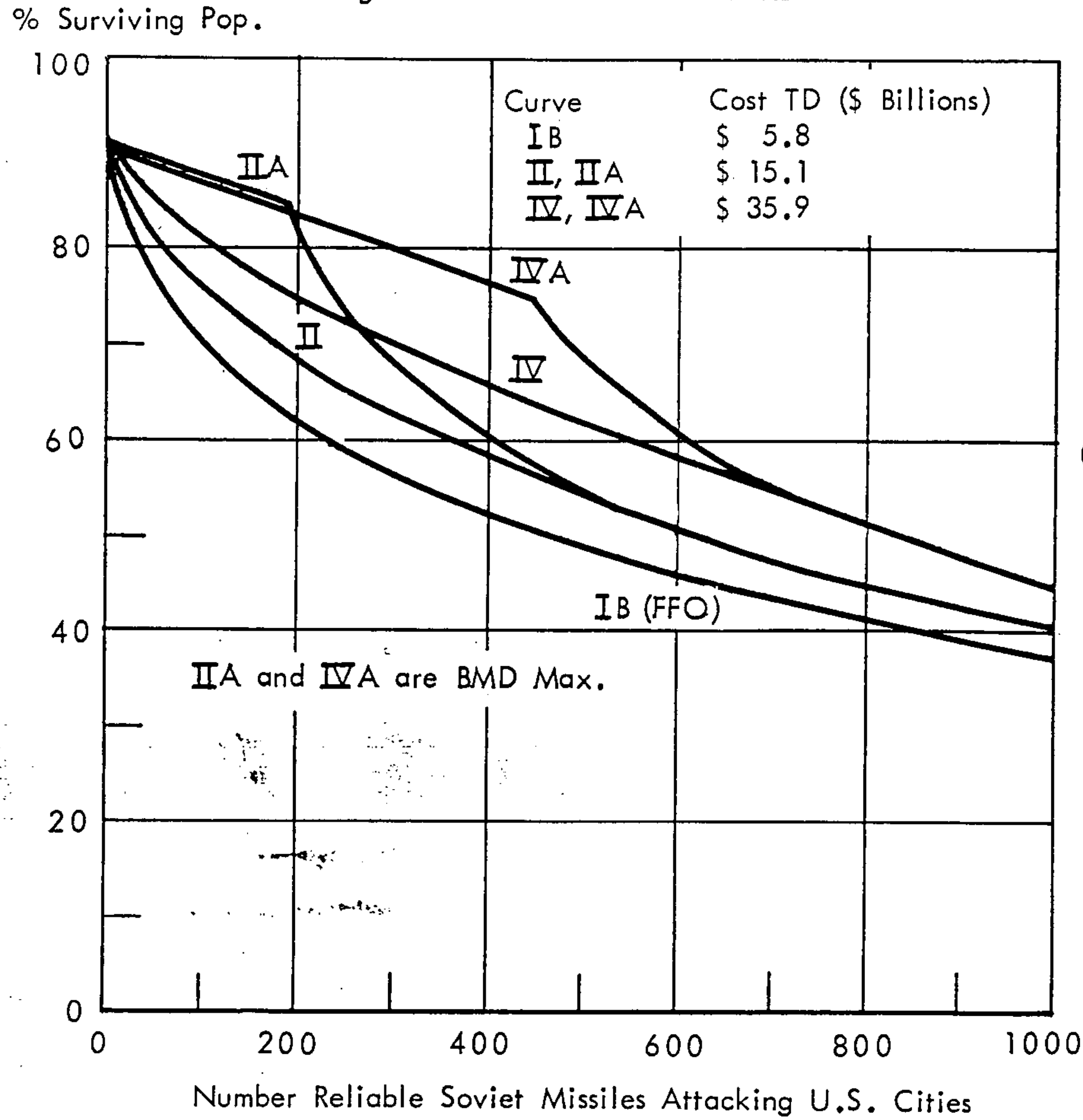

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FIGURE 8 A

% SURVIVING U. S. POPULATION vs NUMBER OF RELIABLE SOVIET MISSILES ATTACKING U. S. CITIES FOR SELECTED TOTAL EXPENDITURES ON TD

-- SHOWING MAXIMUM EFFECT OF BMD --

Same as Figure 8 except Curves II A and IV A are added to show a possible maximum effect of BMD. Maximum effect occurs when Soviets attack targets in order of worth, paying the price for each defended area before attacking undefended targets.

Basic Points

(1) For small to moderate size attacks, the Soviet strategy of attacking targets in order of worth can result in up to an additional 14% saved or a total saving by BMD/TBD of up to 22% for TD expenditure of $15.1 billion (Curve II A). For expenditure of $35.9 billion (Curve IV A), this Soviet strategy can result in up to an additional 10%, or a total saved by BMD/TBD of up to 25%.

(2) Thus due to either (a) poor Soviet attack planning, or (b) unwillingness of the Soviets to attack lower worth undefended targets, leaving high worth targets in major cities intact, the effect of BMD could be much larger than is shown in Figure 8. This holds for attacks of up to 200 to 400 missiles. The real case may be somewhere between the two limits discussed in paragraph 1 above.

(3) Despite the fact that U. S. damage might be considerably less with poor Soviet attack planning, the subsequent analysis, unless otherwise specified, assumes good attack planning on the part of the Soviets. In the final scenarios (Figure 27 and 28) this factor will be included to show the range of possible results.

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Figure 9

% Surviving U.S. Pop. vs % Surviving U.S. MVA
Full Fall-out Shelter Program - All BMD Programs

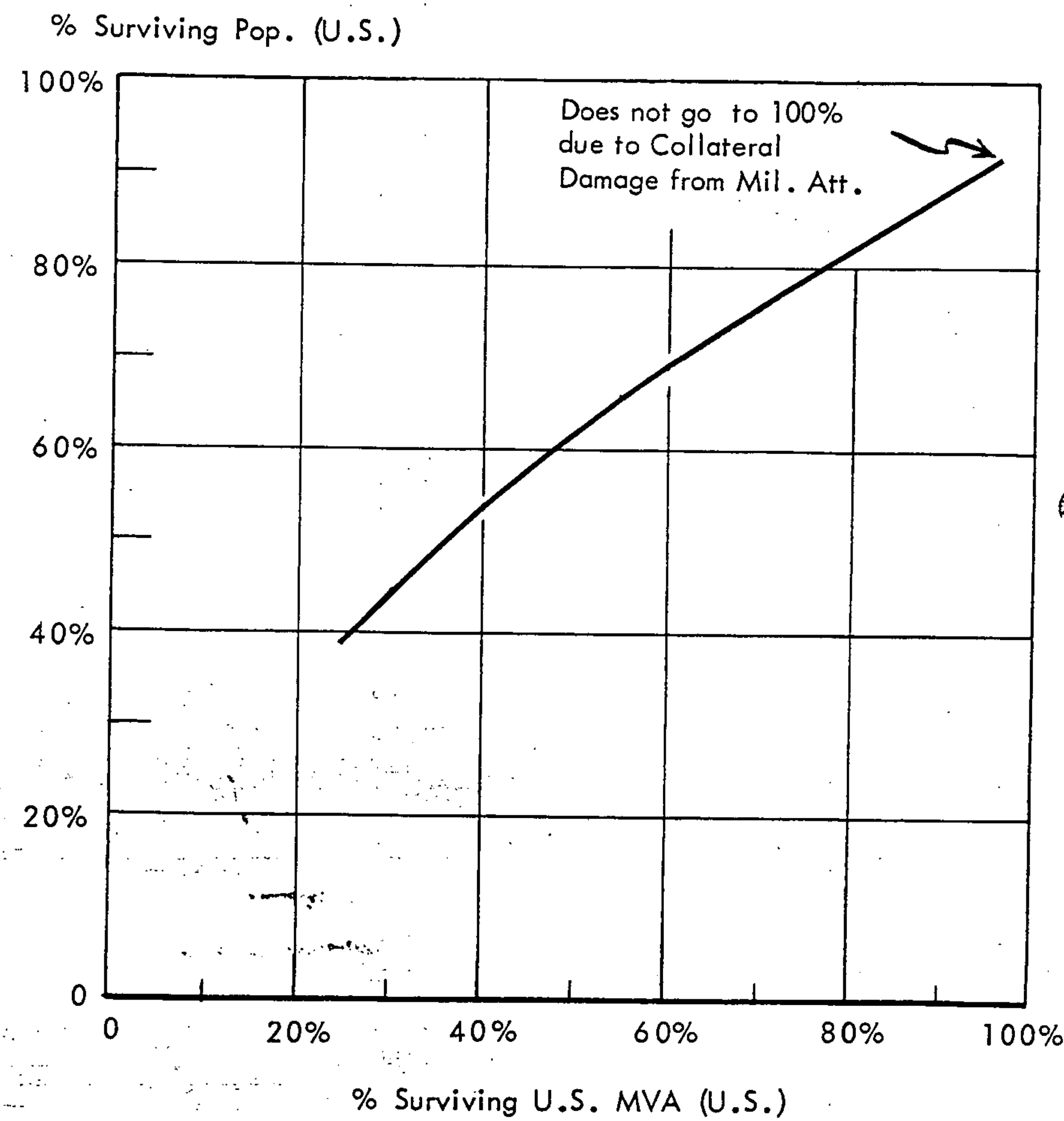

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FIGURE 9

% SURVIVING U. S. POPULATION vs % SURVIVING U. S. MVA
WITH FULL FALLOUT SHELTER PROGRAM

From Figures 7 and 8.

Note: Curve holds (within 2%) for all sizes of BMD programs -- 0 - 60 target areas defended.

(With full fallout shelter program -- principal damage agent for both population and MVA is blast.)

Basic Points

For low "% Surviving MVA" the "% Surviving Population" is up to 15% higher than the MVA level.

For higher "% Surviving MVA" the "% Surviving Population" is about the same as the percent of MVA surviving. For example, at 30% surviving MVA there is 45% surviving population. For 90% surviving MVA, there is also 90% (almost) surviving population.

Figure 10

Ratio of % Surviving $\frac{\text{Population}}{\text{MVA}}$ vs % Surviving MVA

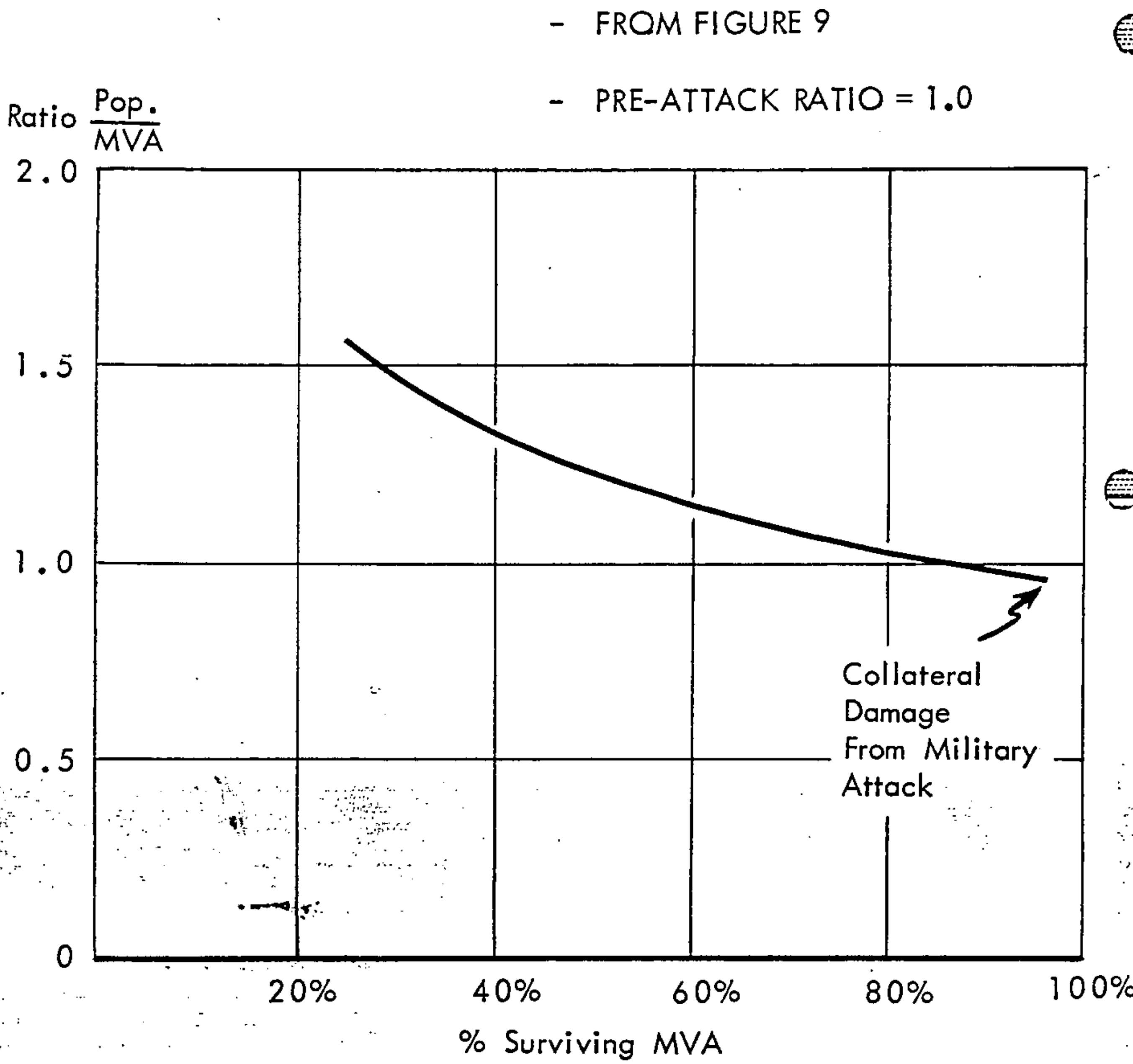


FIGURE 10

$$\text{RATIO OF } \frac{\text{\% SURVIVING POPULATION}}{\text{\% SURVIVING MVA}} \text{ vs \% SURVIVING MVA}$$

Derived from Figure 9.

Basic Points

(1) Ratio equals one for pre-attack case -- by definition. Figure includes effect of collateral damage from military attack. For small attacks or large defense (high % surviving) ratio stays about 1.

(2) As damage increases, imbalance between surviving population and MVA increases.

(3) The main cause for these effects is that MVA is more concentrated than population -- given fallout protection to the population.

Figure 11

Cost TD vs Number of Reliable Soviet Missiles Attacking U.S. Cities for Constant % Surviving U.S. MVA

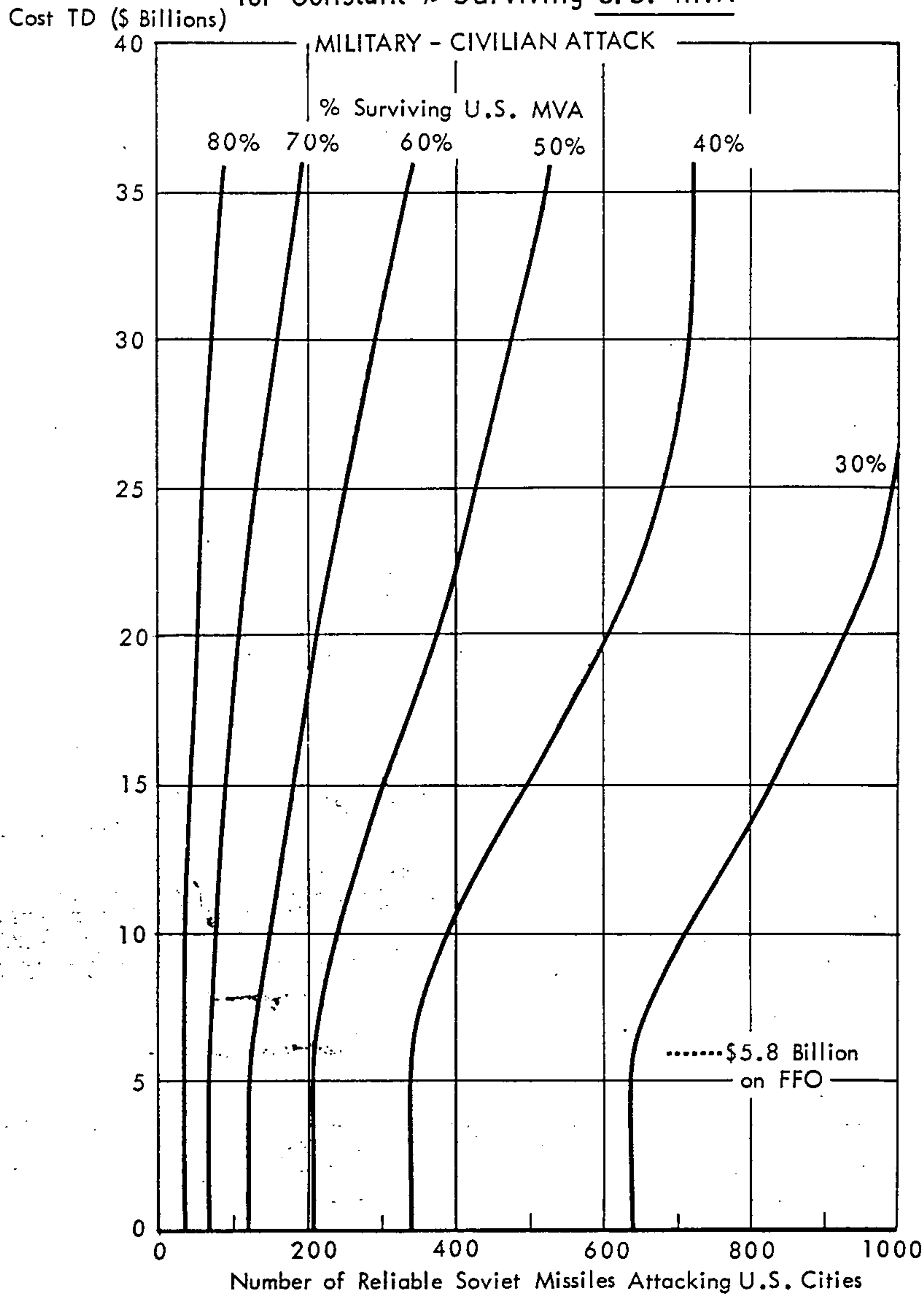


FIGURE 11

COST TERMINAL DEFENSE vs NUMBER OF RELIABLE SOVIET MISSILES ATTACKING U. S. CITIES FOR CONSTANT % SURVIVING U. S. MVA

Allocation of U. S. Defense Dollars

First $5.8 billion spent on CD (no effect on MVA).

Rest of budget allocated to BMD/TBD.

BMD deployment optimized for 400 missile attack (See Figure 2).

Note

(1) The 50%, 40% and 30% surviving curves would be appreciably less steep if the defense designs for each size of attack.

(2) This would not change allocations to Strategic Offensive Forces (SOF) on figures to follow.. (Optimum SOF attack on Soviet forces will reduce Soviet attack on U. S. cities to less than 400 missiles.)

(3) With a full fallout shelter program a particular "% Surviving Population" is uniquely related to a particular "% Surviving MVA". (See Figure 9).

% Surviving MVA	Corresponding % Surviving Population (With FFO)
80%	82%
70%	75%
60%	69%
50%	62%

(4) Cost of Reliable Soviet Missile is taken as $25 million.

Basic Points

(1) A given increase in "% Surviving" for a given attack becomes increasingly expensive at higher levels of "% Surviving MVA". E.g., for a 300 missile attack:

% Surviving MVA	Cost
40%	0
50%	$15 B
60%	$31.5 B
70%	(off graph)

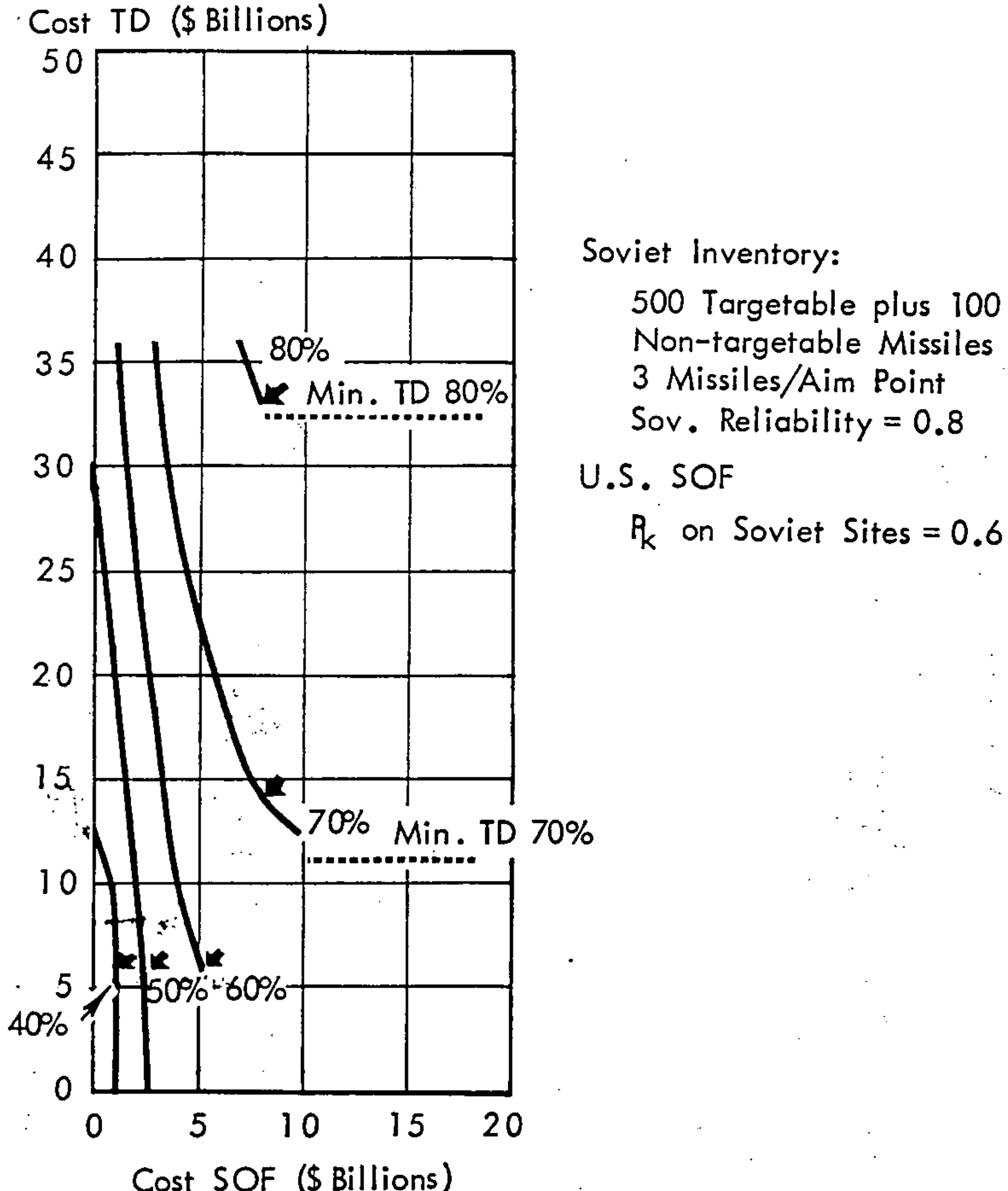
(2) It is increasingly expensive, at higher levels of % Surviving, to offset or negate the effects of an additional attacking missile. Note: To maintain a given level of % Surviving against an increased threat requires TD expenditures at a roughly constant ratio of defense cost per additional missile. (This holds over a wide range as shown by the nearly straight lines on Figure 11).

% MVA	Cost to Offset One Additional Missile
50%	$80 M
60%	$140 M
70%	$260 M
80%	$500 M

(3) Higher % Surviving levels are at an increasingly unfavorable cost ratio to the U. S. (Essentially same point as above but repeated for emphasis).

Figure 12

Cost TD vs Cost Strategic Offensive Forces (SOF) for Constant % Surviving U.S. MVA



[redacted]

FIGURE 12

COST TD vs COST STRATEGIC OFFENSIVE FORCES (SOF) FOR CONSTANT % SURVIVING U. S. MVA

Soviet Inventory

500 targetable plus 100 non-targetable missiles of type described on Figure 2.

Missiles are in hard silos with 3 missiles/aim point. Reliability = 0.8.

Non-targetable missiles that cannot be attacked by U. S. SOF include: (a) Missiles in unknown locations; and (b) SLBM's (On ICBM equivalent payload basis).

Terminal Defense (TD)

Optimized among CD/BMD/TBD. Note: First $5.8 billion for TD on Figure 12 are for CD. Remainder on BMD/TBD, as described on Figures 5 and 11.

Strategic Offensive Forces (SOF)

U. S. SOF P_k on Soviet sites = 0.6 [redacted]

Five year system cost per reliable MINUTEMAN = $12 million.

General

The purpose of this graph is to examine the relative utility (in combination) of "negating" the effects of the attack through TD and reducing the size of the attack by destroying Soviet

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missiles prior to launch with SOF (MINUTEMAN). Basic data is from Figure 11.

Arrows indicate points of optimum expenditure (least cost for given % surviving.

Basic Points

(1) In combination, TD and SOF often yield improved effect for given cost, or given effect for less cost than either used separately.

(2) For minimum total cost, after FFO, first $6-8 billion are spent on SOF.

(3) Because of non-targetable force, high "% Surviving" cannot be attained by means of SOF alone. Horizontal dashed lines on the figure show minimum TD expenditure necessary to negate the effects of non-targetable force, for given "% Surviving".

(4) For Figures 12-14, the programming ratio of reliable U. S. missiles per Soviet aim point can be derived by dividing the cost SOF (in billions) by 2. Programming ratio at optimum point varies with % Surviving, up to a maximum of 4:1. This is a ratio of slightly more than 1 reliable missile/Soviet missile -- assuming 3 Soviet missiles per aim point.

Figure 13

Cost TD vs Cost SOF for Constant % Surviving U. S. MVA

Soviet Inventory: 500 Targetable and
250 Non-targetable Missiles
3 Missiles/Aim Point
Reliability = 0.8

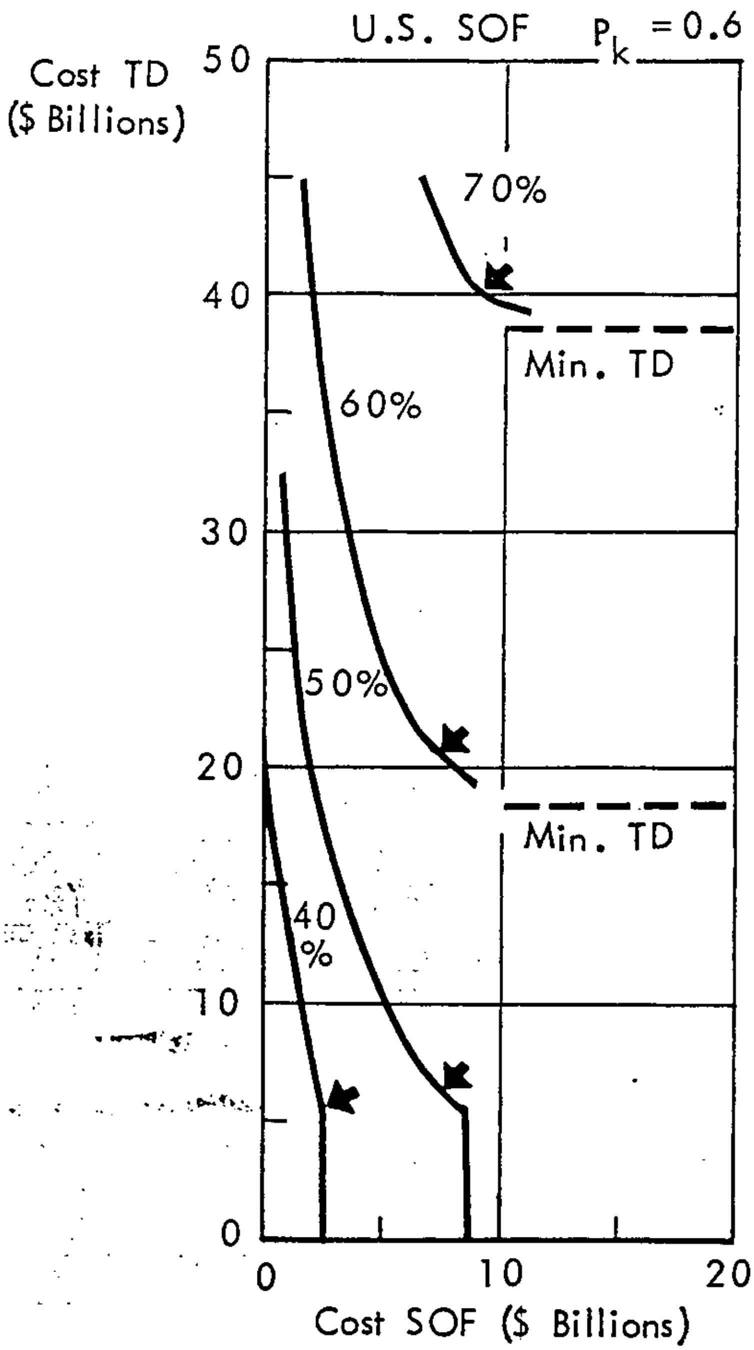

FIGURE 13

COST TD vs COST SOF FOR CONSTANT % SURVIVING U. S. MVA

Conditions same as Figure 12 except: Soviet inventory of 500 targetable plus 250 non-targetable missiles.

Basic Points

(1) Optimum behavior similar to Figure 12.

(2) Cost of achieving given % Surviving rises abruptly in this case (250 non-targetable) from Figure 12 (100 non-targetable).

E.G.: % Surviving	Cost to Get X% Surviving	
	Figure 12	Figure 13
60%	$11 B	$27 B
70%	$22 B	$49 B

(3) Same behavior of programming ratios applies as in Figure 12.

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Figure 14

Cost TD vs Cost SOF for Constant % Surviving U. S. MVA

Soviet Inventory: 500 Targetable Missiles;
200 are planned against U.S. U/I Targets and
250 Non-targetable Missiles.
3 Missiles/Aim Point
U.S. SOF P_k on Soviet Sites = 0.6

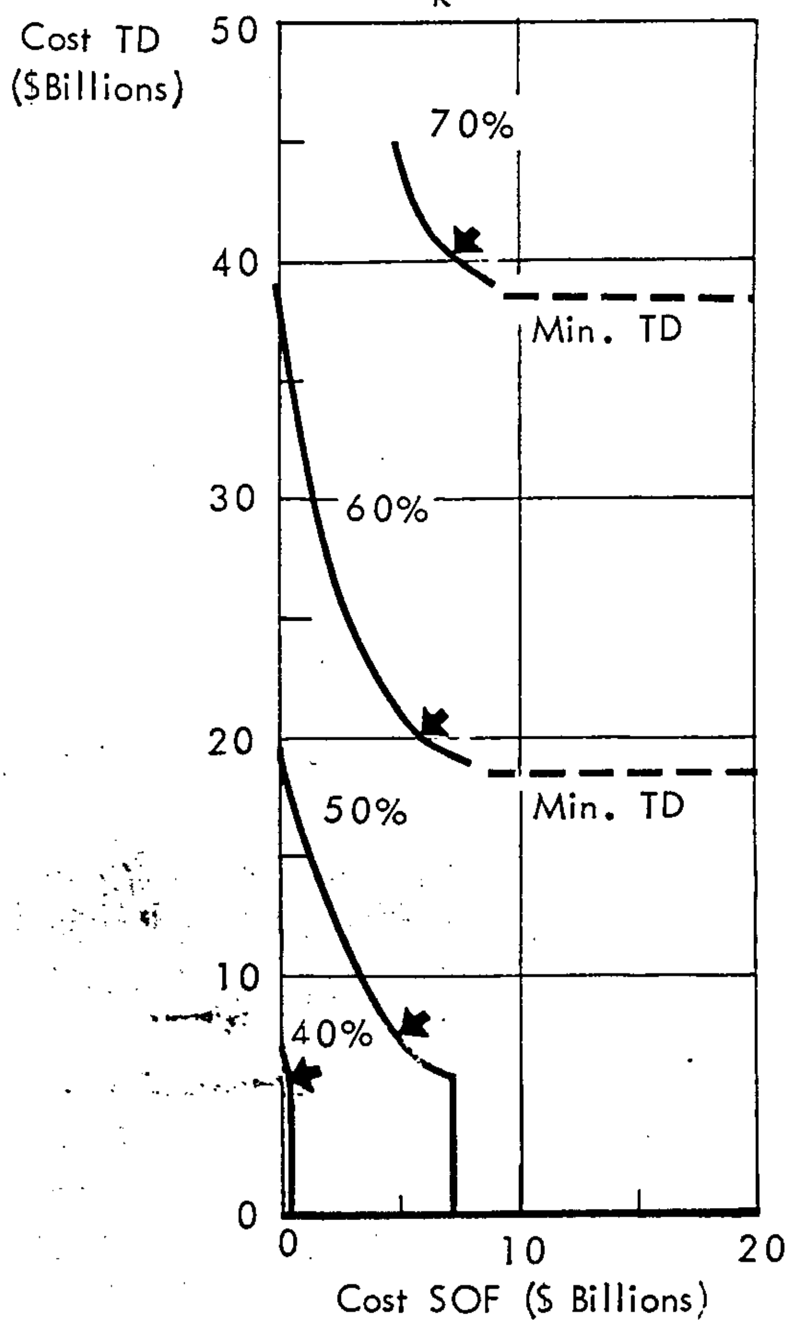

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FIGURE 14

COST TD vs COST SOF FOR CONSTANT % SURVIVING U. S. MVA

Conditions same as Figures 12 and 13 except Soviet inventory now 500 targetable missiles, 200 of which are planned against U. S. cities (U. S. does not know which), plus 250 non-targetable missiles planned against U. S. cities. (In Figures 12 and 13 it was assumed that the total Soviet inventory attacked U. S. cities).

Note: It is immaterial to these calculations whether: (1) the U. S. pre-empts against an intact Soviet missile force but doesn't know which 200 missiles out of the 500 targeted are to be directed against U. S. cities; or (2) the Soviets pre-empt against U. S. military targets but withhold those missiles directed against U. S. cities, and U. S. SOF operates on these Soviet missiles prior to launch. In both cases, the U. S. directs missiles against 167 Soviet aim points which contain 200 missiles planned for U. S. cities.

Basic Points

(1) Same optimum behavior as in Figures 12 and 13, but slightly less allocated to SOF, since it is less effective with so-called "empty holes problem". E.g., optimum allocation for 70% surviving on Figure 13 (no empty holes) -- $9 billion on SOF; on this Figure (empty holes problem) -- $7.5 billion on SOF. This involves a change in programming ratio of reliable U. S. missiles/Soviet aim point from 4:1 to 3.8:1.

(2) The critical assumption here is that the U. S. is targeting 500 missiles at 167 sites, but that only 200 of these missiles are planned for attack against U. S. cities.

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Figure 15

Cost TD vs Cost SOF for Constant % Surviving U.S. MVA

Soviet Inventory: 500 Targetable and
250 Non-targetable Missiles
1 Missile/Aim Point

U.S. SOF P_k on Soviet Sites = 0.6

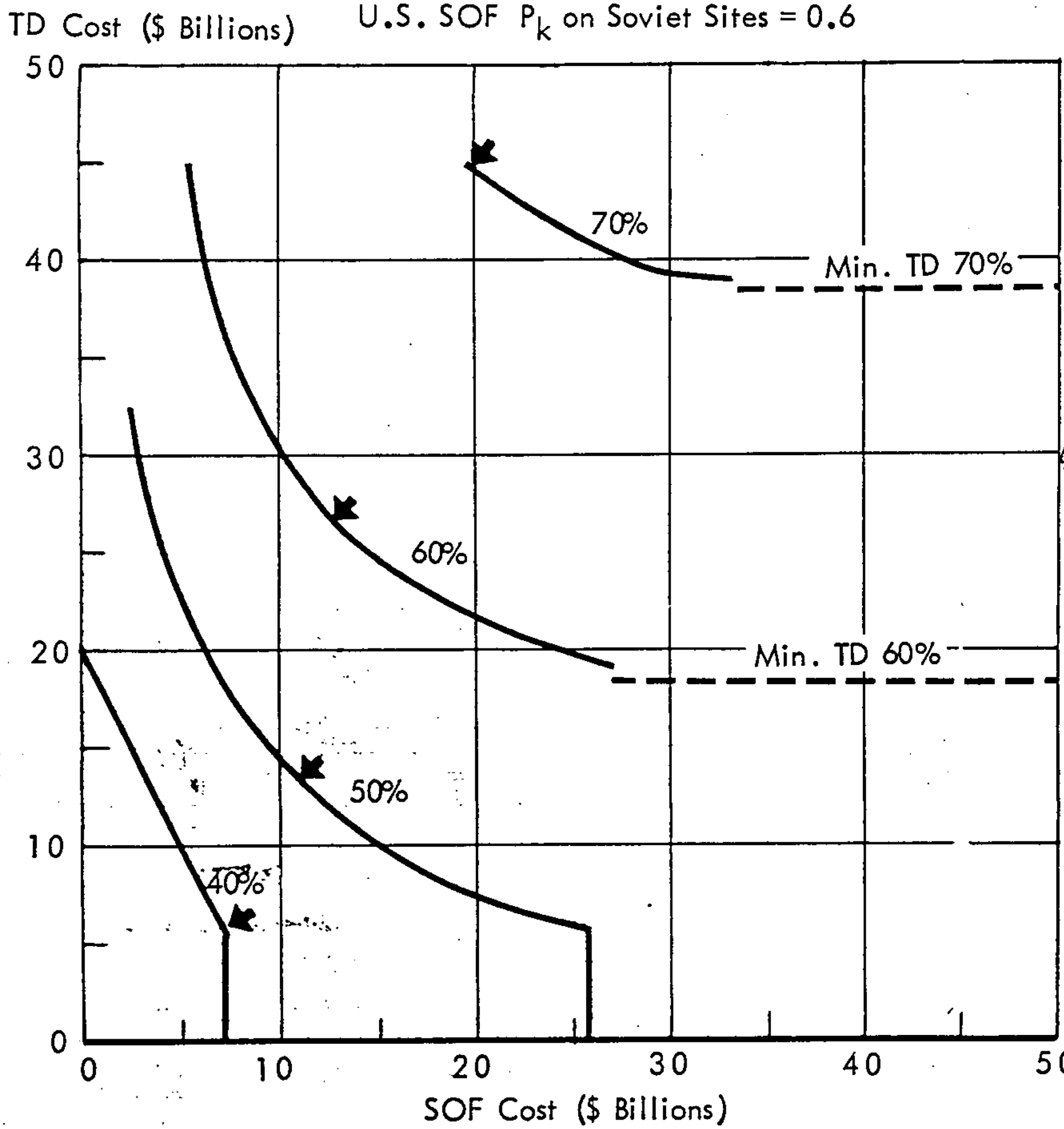

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FIGURE 15

COST TD vs COST SOF FOR CONSTANT % SURVIVING U. S. MVA

Conditions same as Figure 13 (500 targetable plus 250 non-targetable) except now Soviets deploy 1 missile per aim point rather than three.

Basic Points

(1) SOF effectiveness reduced if Soviets improve planning.

(2) U. S. costs to achieve a given "% Surviving MVA" go up markedly. 70% surviving on Figure 13 cost about $27 billion with 3 Soviet missiles/aim point. But it costs $65 billion if Soviets deploy 1 missile/aim point. Costs are thus sensitive to the quality of Soviet planning.

(3) With Soviet missiles dispersed one/aim point, U. S. SOF is less effective (no bargains). Programming ratio of reliable U. S. missiles/Soviet aim point reaches a maximum of 3.3:1. (With one missile per aim point this programming ratio can be derived by dividing SOF cost in billions by 6. In this case (one missile/aim point), a ratio of 3.3 U. S. missiles/Soviet missile is implied, whereas, optimum expenditure in Figures 12-14 (with 3 Soviet missiles/aim point) involved a ratio of only slightly over 1:1 -- on a missile to missile comparison.

FIGURE 16

% SOVIET POPULATION/MVA SURVIVING vs NUMBER OF RELIABLE U. S. MISSILES ATTACKING SOVIET CITIES FOR TWO CD POSTURES

This figure corresponds to Figure 1 for the U. S. case.

Attack

On Soviet MVA targets in order of worth destroyed/missile. Percent MVA surviving is shown by dotted line. Percent population surviving is shown by solid lines.

Weapons: POLARIS A-3 or MINUTEMAN. [redacted] Includes collateral damage (shown here by less than 100% surviving for zero weapons attacking Soviet cities) from 5000 MT delivered on Soviet military targets. This condition assumed for all subsequent analyses.

Civil Defense Postures

Curve	Blast Criterion	Radiation PF	Description
A	6.5 psi	4.2	No civil defense
B	6.5 psi	10	Increased protection factor, modest investment

All following Soviet graphs will be based on this military-civilian attack and assume CD posture B

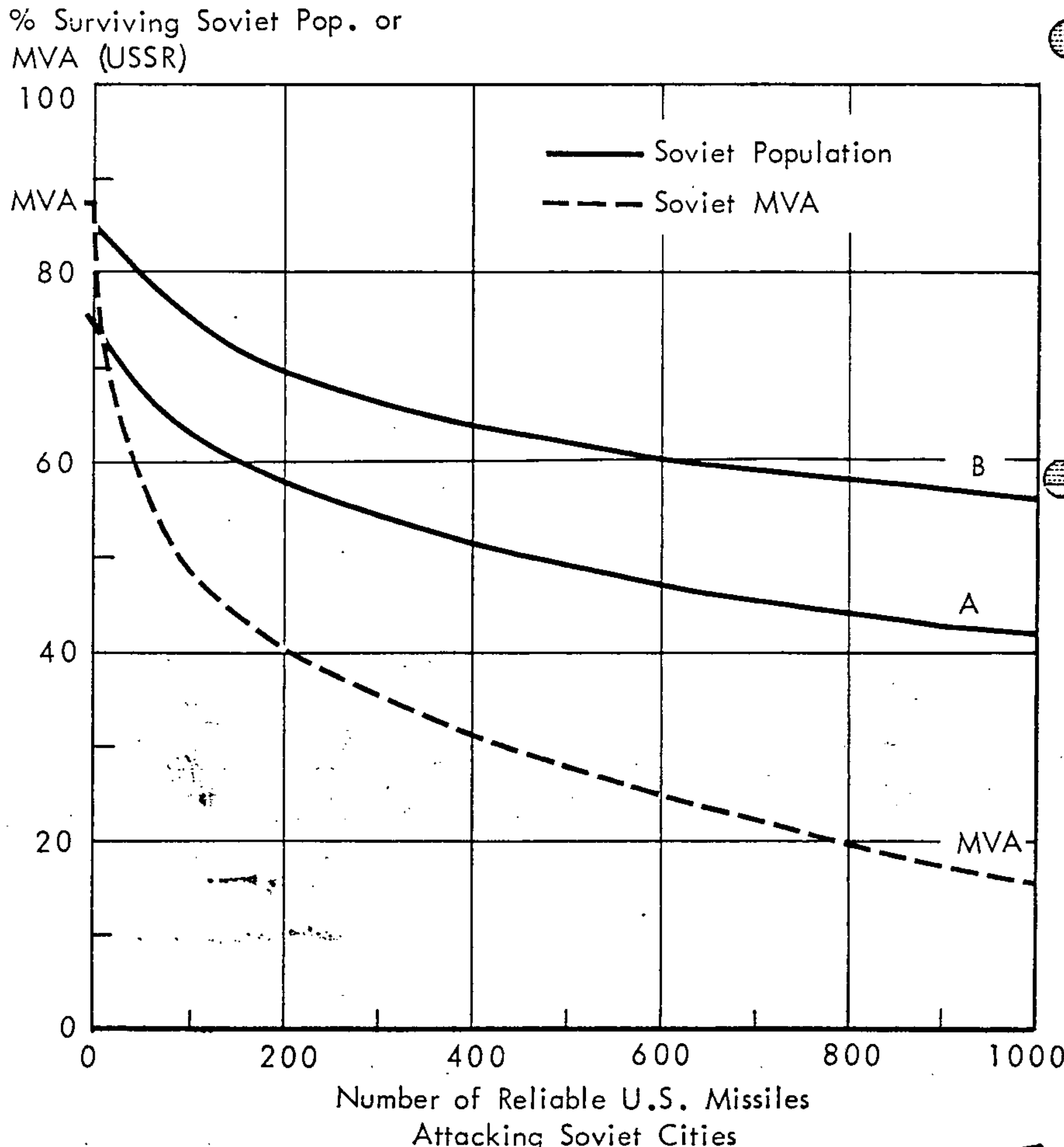
Basic Points

(1) Modest CD investment may increase "% Population Surviving" by up to 14%.

(2) Soviet MVA is more concentrated, thus more easily destroyed than

Figure 16

% Soviet Pop./MVA Surviving vs Number of Reliable U.S. Missiles Attacking Soviet Cities for Two CD Postures Military-Civilian Attack



Soviet population.

(3) Comparison with Figure 1 for the U. S. shows that about equal percentages of U. S. population and U. S. MVA are destroyed by a given sized attack, whereas in the Soviet Union, a given attack destroys a much higher percentage of Soviet MVA than of Soviet population. This is a basic asymmetry in U. S./Soviet urban/ industrial distributions.

Figure 17

Cost of BMD vs Number of Reliable U.S. Missiles Attacking Soviet Cities for Constant % Soviet MVA Surviving

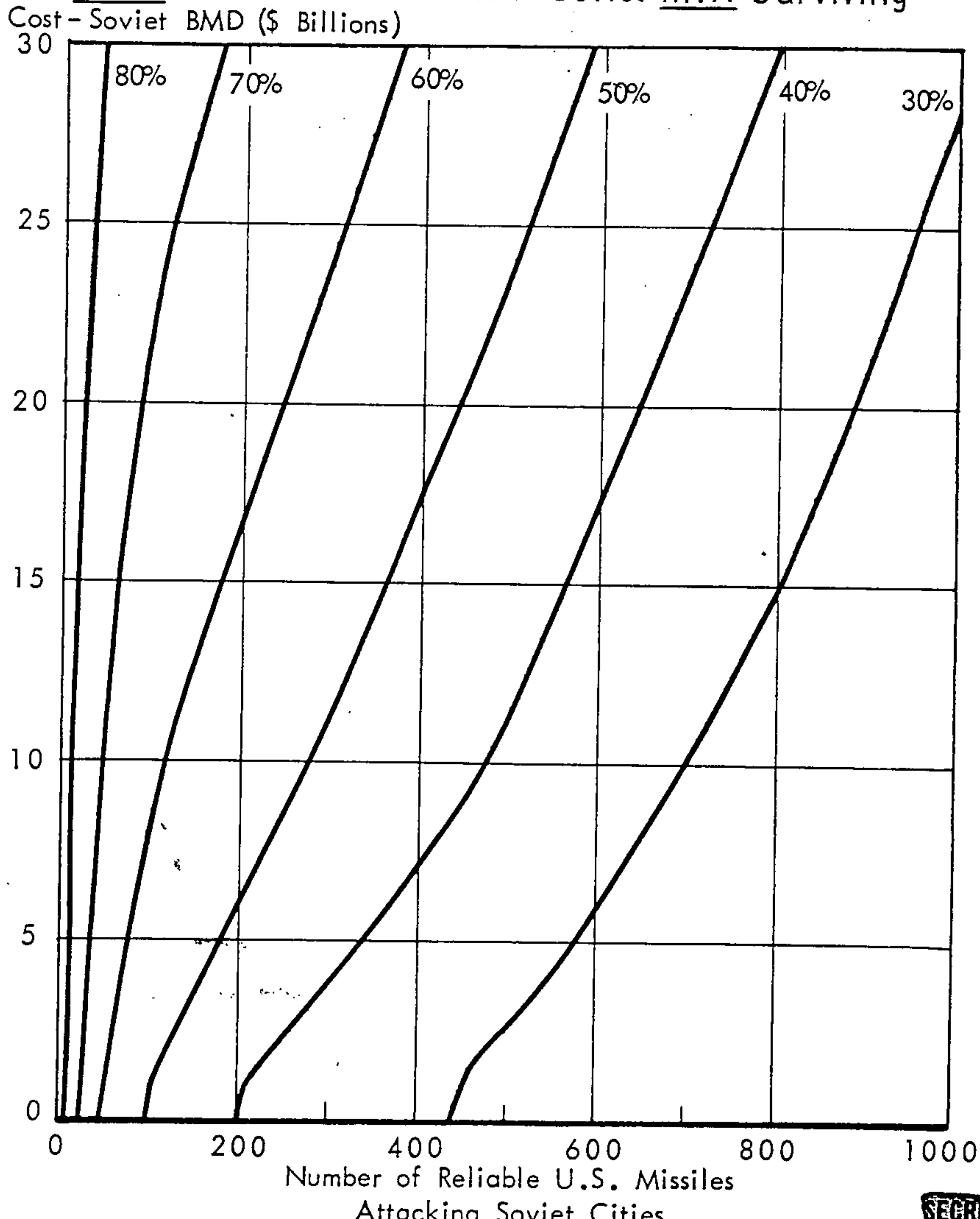


FIGURE 17

COST BMD vs NUMBER OF RELIABLE U. S. MISSILES ATTACKING SOVIET CITIES FOR CONSTANT % SOVIET MVA SURVIVING

This Figure corresponds to Figure 11 for the U. S. case.

Attack

Same as in Figure 16, except attack on defended targets with the equivalent of 1 MT + 7 objects. (POLARIS B-3 which should be operational by the time the Soviets have a NIKE-X type system).

BMD Characteristics

(1) NIKE-X type system assumed, identical with U. S. system described on Figure 2 (and same costs).

(2) BMD deployment optimized for 400 missile attack. If defense designs for each attack size, curves would be less steep.

Basic Points

(1) A given increase in "% Surviving" for a given attack becomes increasingly expensive at higher levels of surviving MVA. E.g., for a 200 missile attack:

% Surviving	Cost	Incremental Cost
40%	$0	
50%	$6 B	$6 B
60%	$17 B	$11 B
70%	$31 B (extrapolated)	$14 B

(2) At higher % Surviving levels it is increasingly costly for the

Soviets to negate the effects of an additional missile. (Curves are progressively steeper). Note: To maintain a given level of defense against an increased attack size requires a roughly constant ratio of defense cost per additional missile (curves are roughly straight lines over a wide range).

% Surviving MVA	Cost to Offset One Additional Missile Soviet	U. S. (From Figure 11)
50%	$65 M	$80 M
60%	$75 M	$140 M
70%	$310 M	$260 M
80%	$750 M	$500 M

(3) At low "% Surviving" the Soviet cost to offset one additional missile is less than the corresponding figure for the U. S., but the relationship reverses for higher "% Surviving". Several competing factors combine to bring about this condition, namely: (1) differences in MVA concentration (Soviet's more concentrated. This makes it easier to defend against small attacks but concentration hurts for case of large attacks;) (2) size of missiles (Soviet's are larger); and (3) amount of collateral damage from military attack (collateral MVA damage from military attack is 13% in the Soviet Union, 4% in the U. S. Thus, for high % Surviving on both sides, the Soviets must limit U/I attack damage to a greater degree than must the U. S.)

Figure 18

Cost of BMD vs Number of Reliable U.S. Missiles Attacking Soviet Cities for Constant % Soviet Population Surviving

CD POSTURE "B"

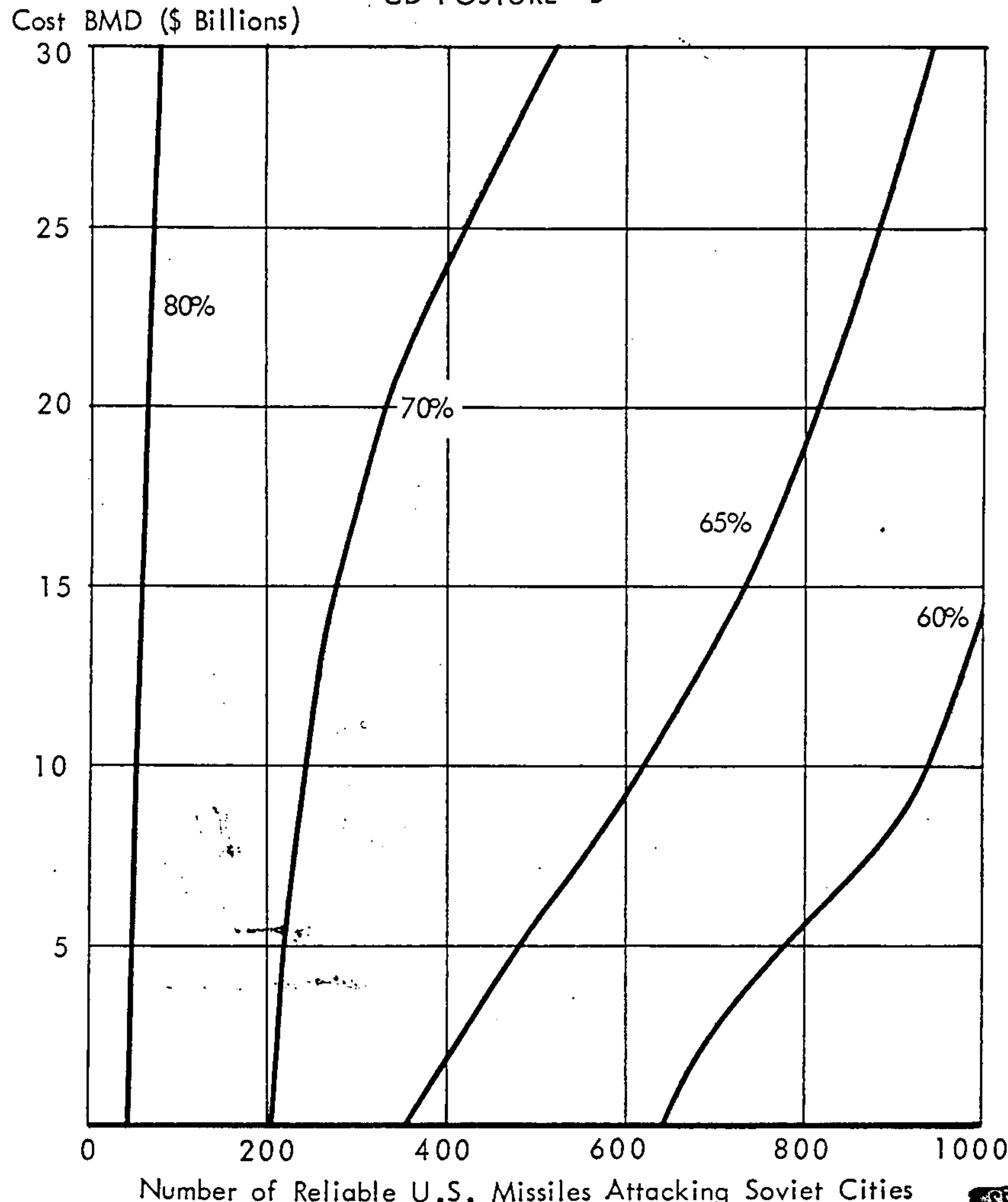


FIGURE 18

COST BMD vs NUMBER OF RELIABLE U. S. MISSILES ATTACKING SOVIET CITIES FOR CONSTANT % SOVIET POPULATION SURVIVING

Conditions same as for Figure 17 except this chart is for population rather than MVA.

Basic Points

(1) 60%-80% of Soviet population survives for wide range of attacks, and/or wide range of BMD expenditure.

(2) Cost of offsetting an additional missile increases at high "% Surviving", rising from $70 million at 65% surviving to $750 million at 80% surviving.

Figure 19

Cost BMD vs Cost SOF for Constant % Surviving Soviet MVA

U.S. Inventory:
1000 Targetable Missiles
1 Missile/Aim Point
Reliability = 0.75
Soviet SOF: P_k = 0.6; Readiness x Reliability = 0.6 - 0.65

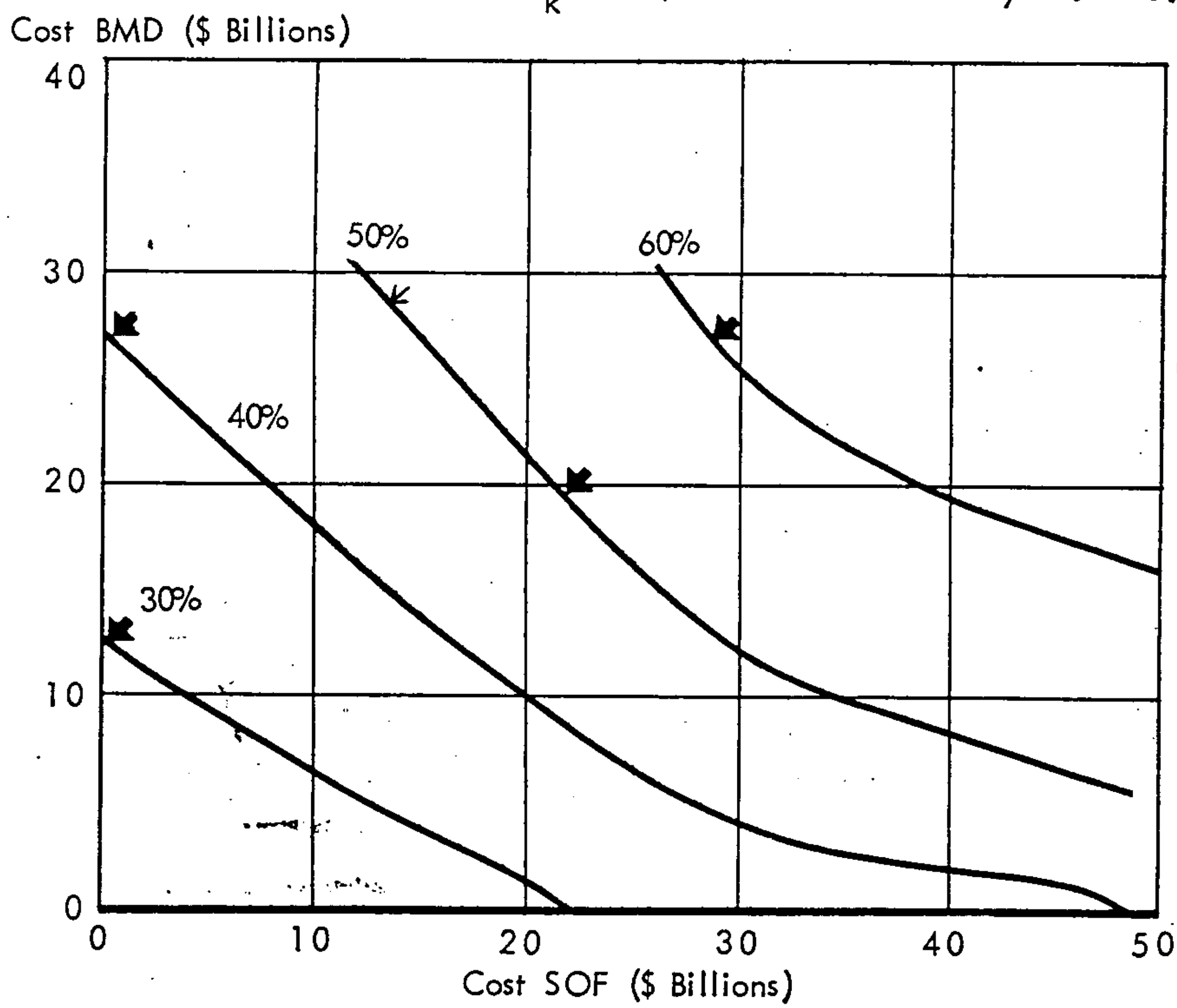


FIGURE 19

COST BMD vs COST SOF FOR CONSTANT % SURVIVING SOVIET MVA

Figures 19 through 21 correspond to Figures 12 to 15 for the U. S. case.

U. S. Inventory

1000 targetable missiles of type described in Figures 16 and 17.

Note: In this graph all U. S. missiles are assumed targetable to give best advantage to Soviet SOF. Final result will be independent of this assumption.

Reliability of U. S. missiles = 0.75. Note: Readiness is only included when missiles are against time urgent targets, i.e. SOF operations. This concept is applied to both sides.

1 missile/aim point.

Soviet BMD costs and characteristics as described on Figures 2 and 17.

SOF

Soviet SOF P_k on U. S. Sites = 0.6. (Soviets probably cannot do this well. Final results are independent of this assumption).

Soviet Missile Readiness X Reliability = 0.6 - 0.65.

Cost per reliable Soviet missile = $25 million.

Arrows indicate points of optimum expenditure (least cost for given "% Surviving").

Basic Points

(1) Again, as in the U. S. case, combinations of BMD and SOF often yield given "% Surviving" at lower cost than either alone.

(2) Since Soviet missiles are more costly and are still assumed to have about the same P_k as U. S. missiles, SOF is less effective as a damage limiting agent for the Soviets than for the U. S. Thus, in contrast to U. S., Soviet's most economical option is to allocate first to BMD; only after around $20 billion start spending on SOF.

(3) It should be noted that here the Soviet planner assumes all U. S. missiles will be targeted against Soviet cities.

(4) This is the most favorable case for Soviet SOF -- there is no "empty holes problem" to diminish the utility of Soviet SOF.

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Figure 20

Cost BMD vs Cost SOF for Constant % Surviving Soviet MVA

U.S. Inventory: 1000 Targetable Missiles
1/2 for Soviet Cities
Reliability = 0.75
1 Missile/Aim Point

Soviet SOF: P_k = 0.6; Readiness x Reliability = 0.6-0.65

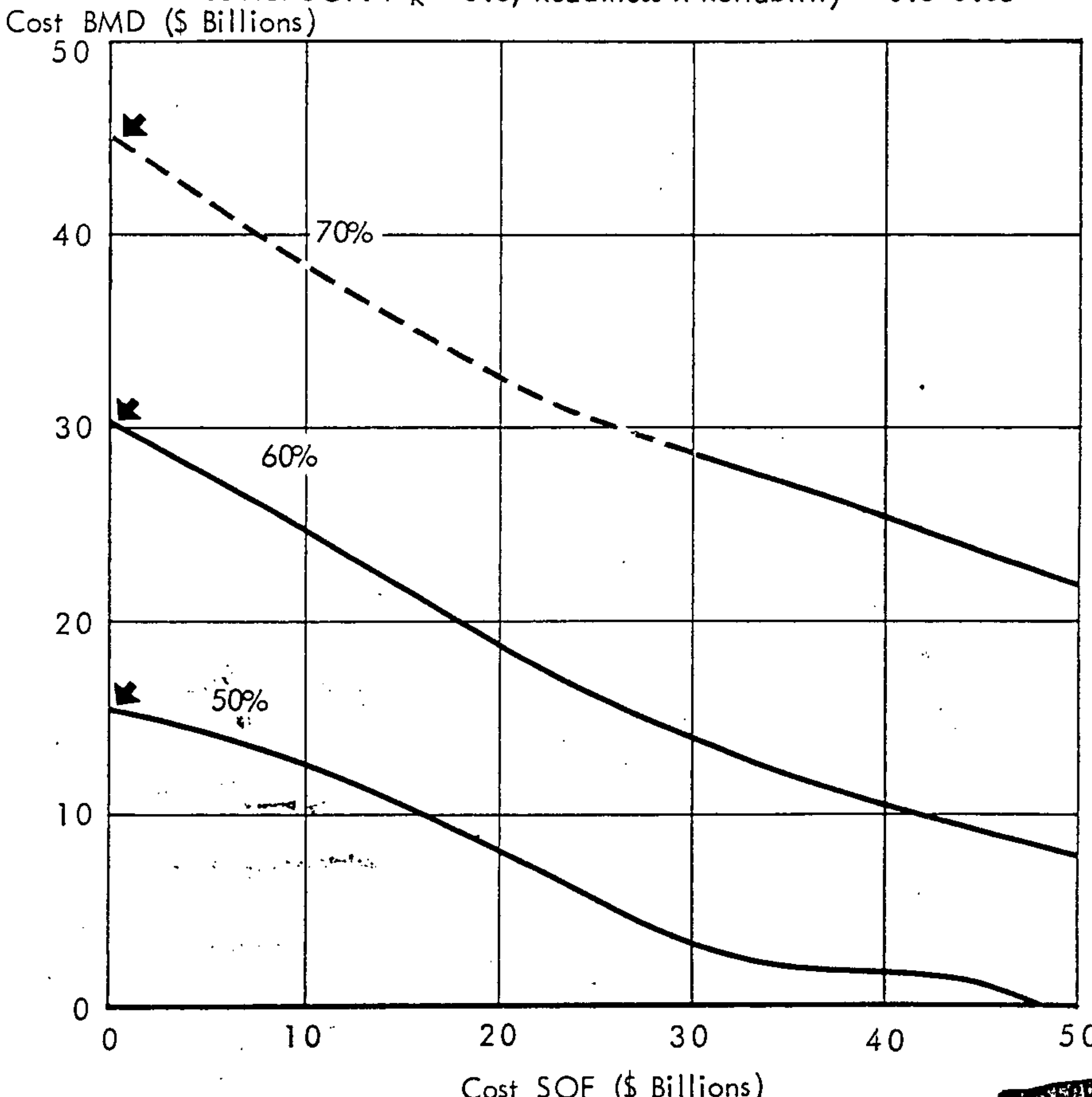

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FIGURE 20

COST BMD vs COST SOF FOR CONSTANT % SURVIVING SOVIET MVA

Conditions same as Figure 19 except U. S. inventory of 1000 targetable missiles, one-half of which are planned for attack of Soviet cities.

Basic Points

(1) Soviet SOF damage limiting effectiveness is diminished when more U. S. missiles are targeted by Soviets than are actually planned to be used against Soviet cities. (Soviets have an "empty holes problem").

(2) In this case Soviet SOF is less effective relative to terminal defense as a damage limiting agent for Soviets than for U. S.

(3) This behavior is reinforced by the existence of a considerable number of U. S. POLARIS missiles that cannot be targeted by Soviet ICBM's -- this makes Soviet SOF damage limiting operations even less effective.

(4) It is never optimal under these conditions for the Soviets to employ SOF for damage limiting.

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Figure 21

Cost BMD vs Cost SOF for Constant % Surviving Soviet MVA

U.S. Inventory: 1000 Targetable Missiles
Reliability ≐ 0.75
1 Missile/Aim Point

Soviet SOF: $P_k = 0.3$; Readiness x Reliability = 0.6–0.65

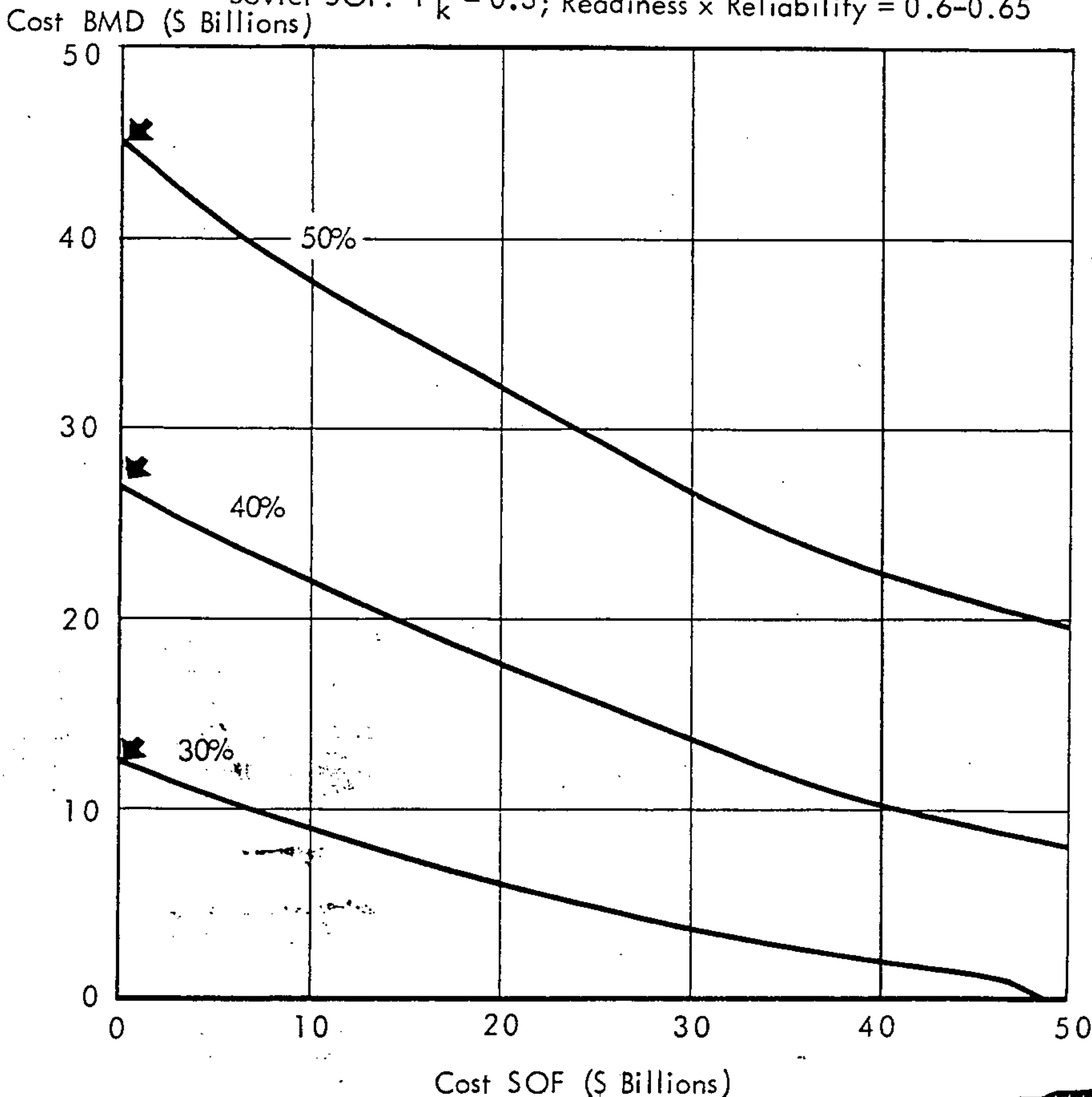

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FIGURE 21

COST BMD vs COST SOF FOR CONSTANT % SURVIVING SOVIET MVA

Conditions same as Figure 19, except: Soviet SOF P_k on U. S. sites = 0.3 rather than 0.6.

Basic Point

If Soviet SOF P_k is less than 0.6 and/or the U. S. plans only a fraction of its missiles against Soviet cities (Figure 20), it is not optimal for the Soviets to employ SOF in damage limiting.

Figure 22

Cost U. S. Damage Limiting vs Cost Soviet Attack on U. S. Cities for Constant % Surviving U. S. MVA

All Soviet Inventories include: 250 Non-targetable Missiles (First $5 Billion of Soviet Cost)
3 Soviet Missiles/Aim Point

U.S. SOF: $P_k = 0.6$

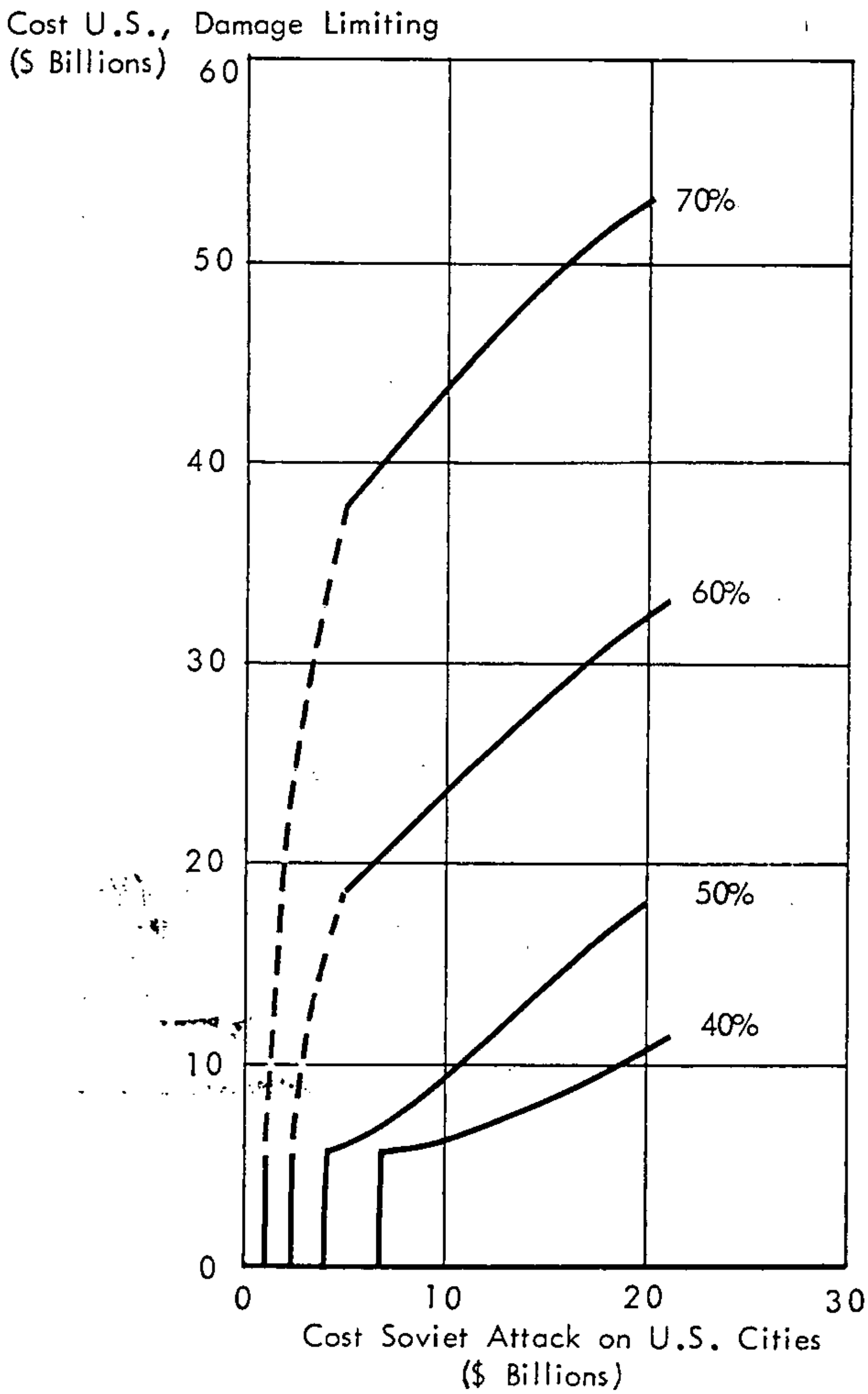


FIGURE 22

COST U. S. DAMAGE LIMITING vs COST SOVIET ATTACK ON U. S. CITIES FOR CONSTANT % SURVIVING U. S. MVA

3 SOVIET MISSILES/AIM POINT

Soviet inventories include 250 non-targetable missiles (Shown in Figure as first $5 billion spent by Soviets). Non-targetable missiles include: (a) ICBM's of unknown location; and (b) SLBM force, etc. (on ICBM equivalent payload basis).

Soviet costs are $20 million per deployed missile of .8 reliability.

Figure depends on Figures 11, 13 and related calculations.

U. S. SOF $P_K = 0.6$.

Basic Points

(1) This graph may be viewed as the competition between "U. S. Damage Limiting" and "Soviet Damage Inflicting".

(2) A large Soviet non-targetable force raises U. S. costs to negate that force (can be done by TD only).

(3) Beyond the negation of the non-targetable force, the U. S./Soviet incremental cost ratio (cost to offset additional Soviet expenditure) is about 1:1. The total cost ratio (total U. S. vs total Soviet costs) includes the accommodation of the non-targetable force and varies with the % Surviving.

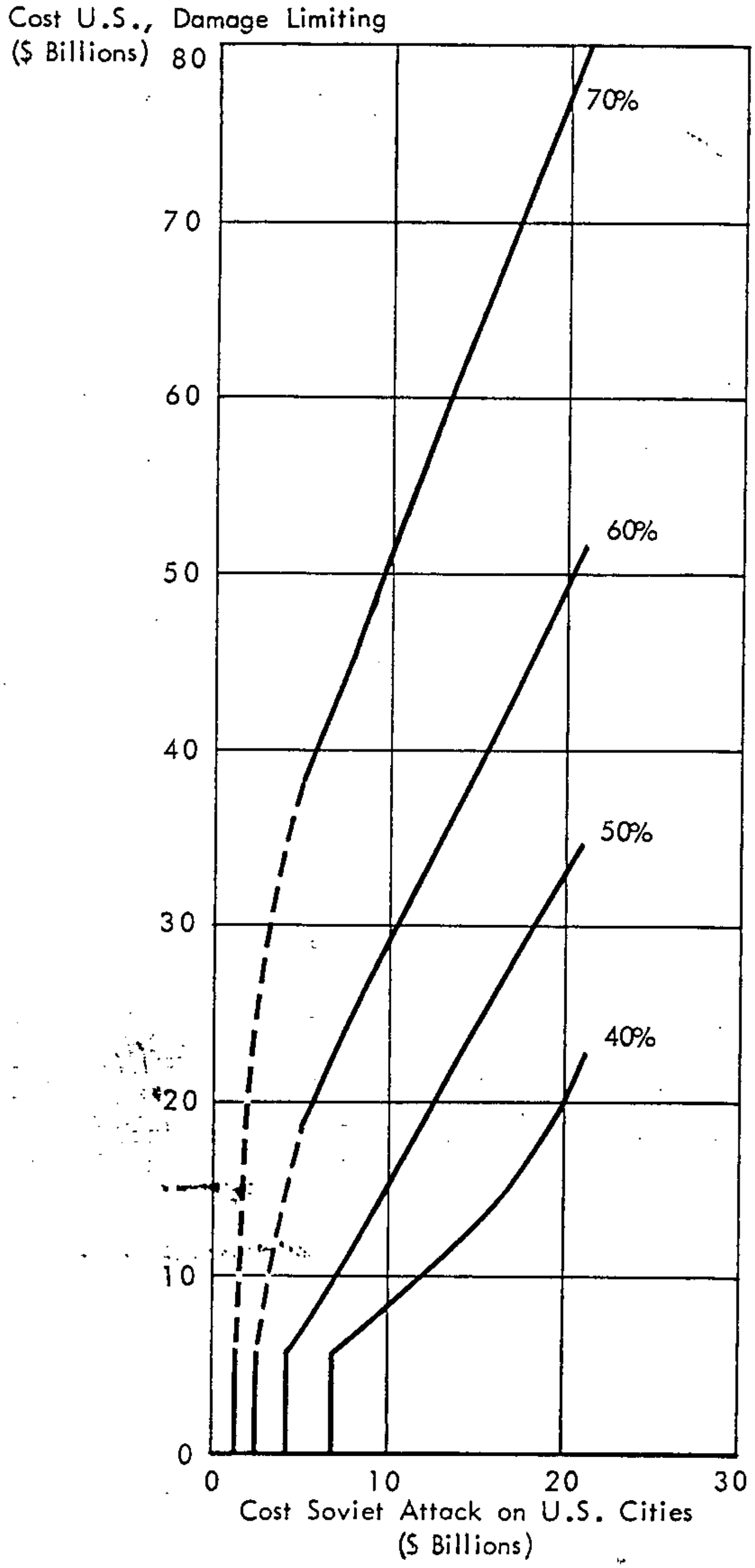
* % Surviving U.S. MVA	* % Surviving U. S. Population	** Incremental Cost Ratio U.S./Soviet	** Approx Total Cost Ratio
40%	54%	0.5:1	0.5:1
50%	62%	0.9:1	0.9:1
60%	69%	0.9:1	1.9:1
70%	75%	0.9:1	3.3:1

* From Figure 9.

** All cost ratios measured at $15 billion Soviet expenditure.

Figure 23

Cost U.S. Damage Limiting vs Cost Soviet Attack on U.S. Cities for Constant % Surviving U.S. MVA



All Soviet Inventories Include:
250 Non-targetable Missiles
1 Soviet Missile/Aim Point

U.S. SOF:
$P_k = 0.6$

FIGURE 23

COST U. S. DAMAGE LIMITING vs COST SOVIET ATTACK ON U. S. CITIES FOR CONSTANT % SURVIVING U. S. MVA

1 SOVIET MISSILE/AIM POINT

Same as Figure 22 except with better Soviet planning -- 1 missile/aim point rather than 3 missiles/aim point.

Basic Points

(1) Deployment at 1 missile/aim point raises U. S./Soviet cost ratios:

% Surviving U. S. MVA	* % Surviving U. S. Population	** Incremental U. S./Soviet Cost Ratio	** Total U. S./Soviet Cost Ratio
40%	54%	1:1	0.9:1
50%	62%	1.8:1	1.6:1
60%	69%	2:1	2.6:1
70%	75%	3:1	4.3:1

* From Figure 9.

** All ratios measured at $15 billion Soviet cost.

(2) Incremental cost ratio is now much more dependent on the % Surviving, and is 2 to 3 times larger than for the case of Soviet ~~deployment~~ of 3 missiles/aim point.

Figure 24

Cost Soviet Damage Limiting (BMD only) vs Cost U.S. Attack on Soviet Cities for Constant % Surviving Soviet MVA

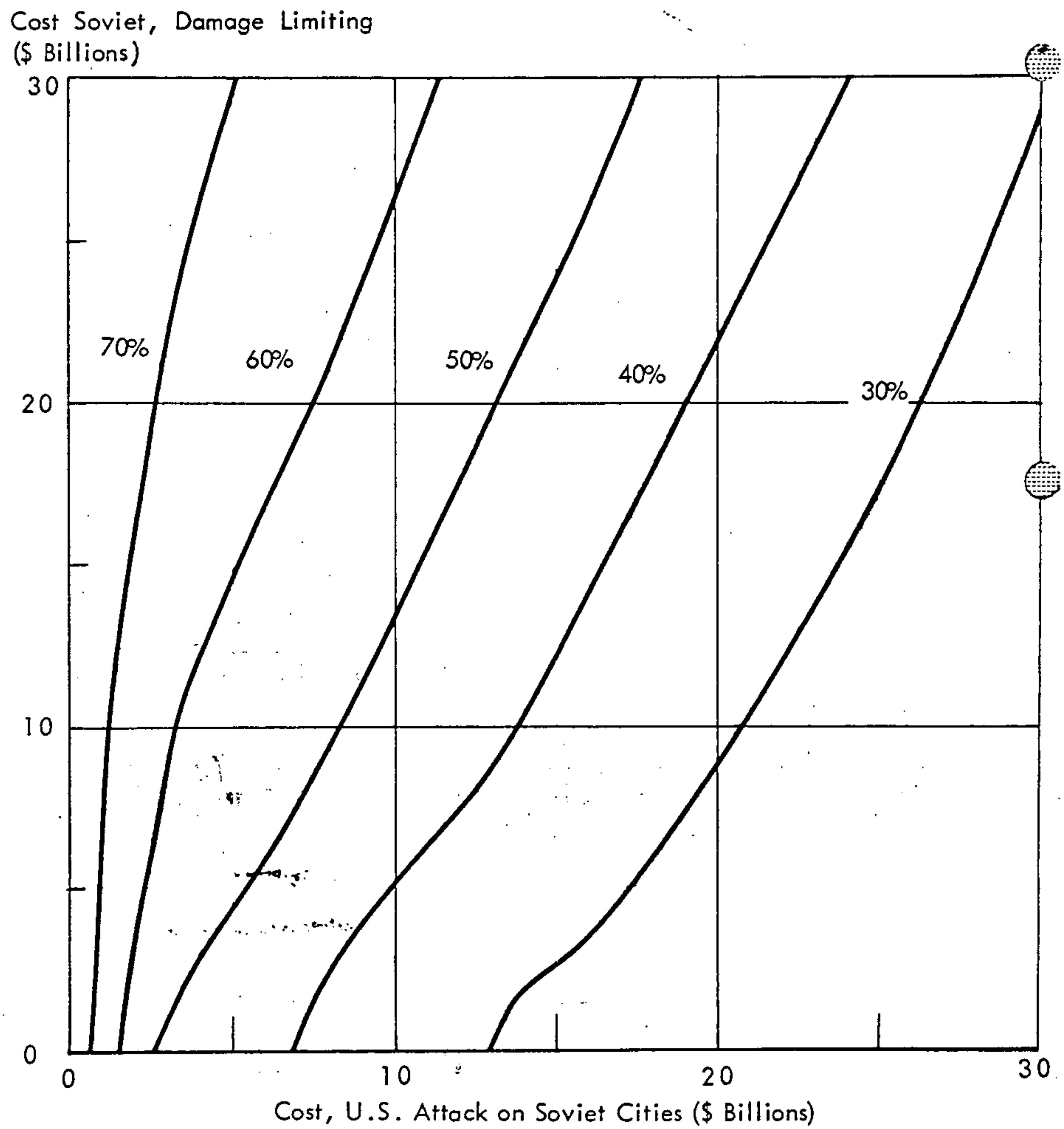


FIGURE 24

COST SOVIET DAMAGE LIMITING (BMD ONLY) vs COST U. S. ATTACK ON CITIES FOR CONSTANT % SURVIVING SOVIET MVA

Notes

(1) This corresponds to Figures 22 and 23 for the U. S.

(2) Figure calculated directly from Figure 17 with costs of $30 million per U. S. reliable on-station missile (mixture of POLARIS A-3, B-3 (against defended targets), and some MINUTEMAN).

(3) Soviet CD program costs not included.

(4) BMD is best Soviet option in damage limiting. (No SOF). See Figures 19-21.

Basic Points

(1) Defense/offense cost ratios for damage limiting are higher for the Soviets than for U. S. Soviet SOF (unlike U. S.) is too expensive, relative to BMD.

(2) Cost ratio increases as "% Surviving" increases.

% Surviving MVA	Incremental Cost Ratio: Soviet/U. S.	* Total Soviet/U.S. Cost Ratio
40%	1.9:1	0.8:1
50%	2.1:1	1.6:1
60%	2.4:1	2.7:1
70%	5.1:1	Off Graph

* Taken at $15 billion U. S. cost.

Figure 25

Number of Reliable U.S. Missiles vs Number of Soviet Missiles for Equal % Surviving MVA in Both Countries and for 0, 30 and 60 Defended Targets (BMD)

Figures denote % surviving MVA in both countries.

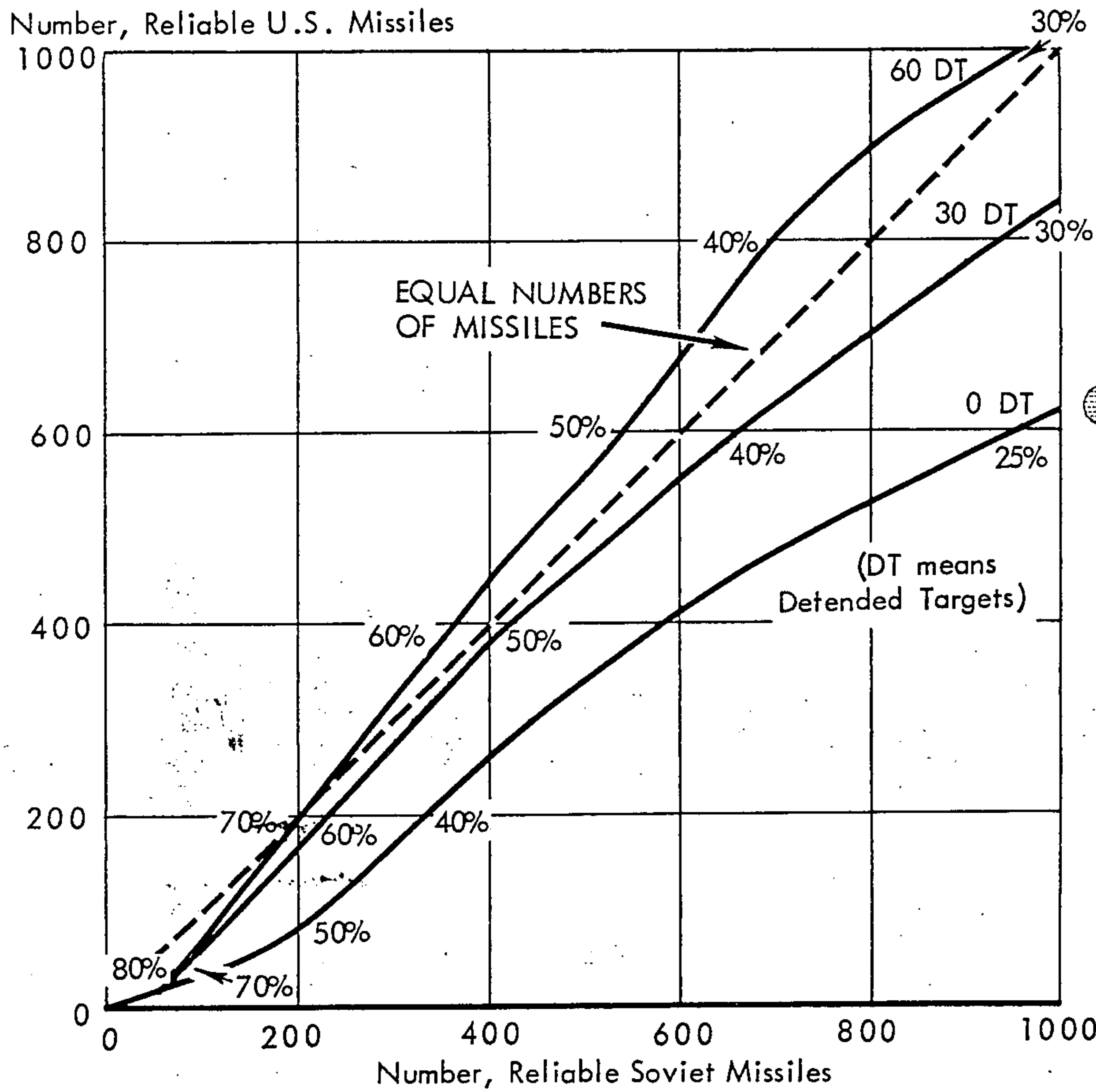


FIGURE 25

NUMBER OF RELIABLE U. S. MISSILES vs NUMBER OF RELIABLE SOVIET MISSILES FOR EQUAL % SURVIVING MVA IN BOTH COUNTRIES AND FOR SELECTED LEVELS OF BALLISTIC MISSILE DEFENSE IN BOTH COUNTRIES

Defenses optimized as described in Figure 2.

Attacks as described in Figures 2, 16, and 17.

Note

It is not assumed that "Equal Damage" is a valid Measure of Merit. Lines of "Equal Damage" are presented only as a means of comparison.

Basic Points

(1) As both countries increase BMD the ratio of the number of U. S. missiles to Soviet missiles to effect the same damage to MVA in both countries moves in favor of the Soviets. At 0 targets defended, more Soviet missiles than U. S. missiles are required; at 60 targets, slightly more U. S. than Soviet missiles are required to effect equal damage.

(2) It should be noted that U. S. missiles are the equivalent of 1 MT whereas Soviet missiles are the equivalent of 5 MT.

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Figure 26

Number of Reliable U.S. Missiles vs Number of Soviet Missiles for Equal % Surviving Population in Both Countries for Selected CD Postures in Both Countries

Figures denote % Surviving Population in Both Countries

X: 100% Fallout Protection (Blast Only)

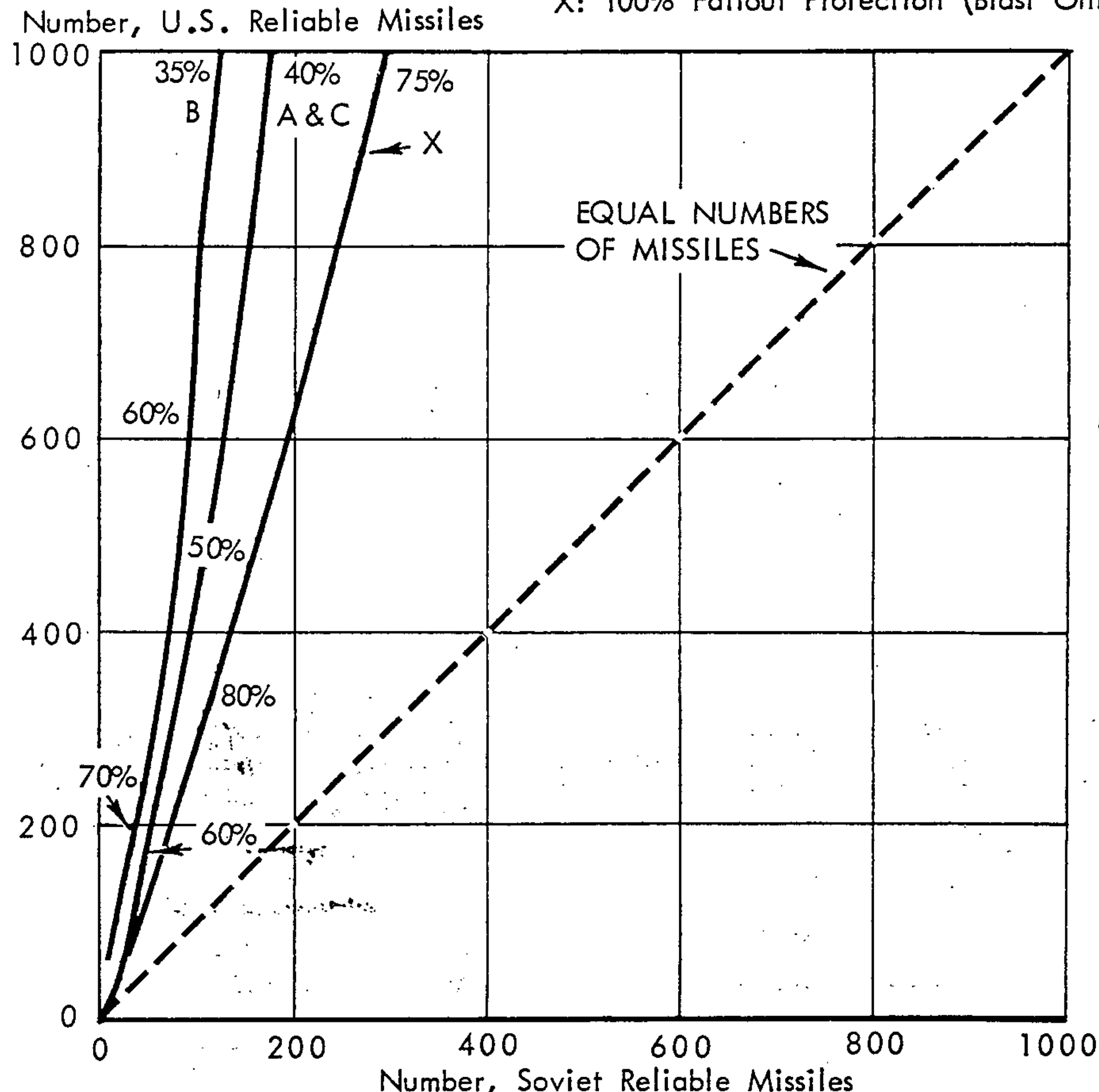

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FIGURE 26

NUMBER OF RELIABLE U. S. MISSILES vs NUMBER OF RELIABLE SOVIET MISSILES FOR EQUAL % SURVIVING POPULATION IN BOTH COUNTRIES FOR VARIOUS CD POSTURES IN BOTH COUNTRIES

Same as Figure 25 except this Figure is for population rather than MVA.

Defenses optimized as described in Figure 2.

Attacks described in Figures 2, 3, 16 and 17.

CD postures A, B, C are described on Figure 1. Soviet curve for C is estimated here.

Note

It is not assumed that "Equal Damage" is a valid Measure of Merit. Lines of "Equal Damage" are presented only as a means of comparison.

Basic Points

(1) More U. S. than Soviet missiles are required to effect equal population damage. Soviet population is much more dispersed and thus much less vulnerable than U. S. population.

(2) High levels of fallout protection swing the ratio toward fewer U. S. missiles than Soviet missiles to effect equal damage. But even at 100% protection from fallout (blast fatalities only), one Soviet missile has about the same effect on population as three U. S. missiles.

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Figure 27

% Surviving U.S. MVA vs Number of Soviet (Inventory) Missiles Against U.S. Cities

Soviet Inventory: 500 Targetable plus 250 Non-targetable Missiles
Reliability = 0.8
3 Missiles/Aim Point

U.S. Allocates $28.1 Billion (Provides for 60% Surviving MVA)

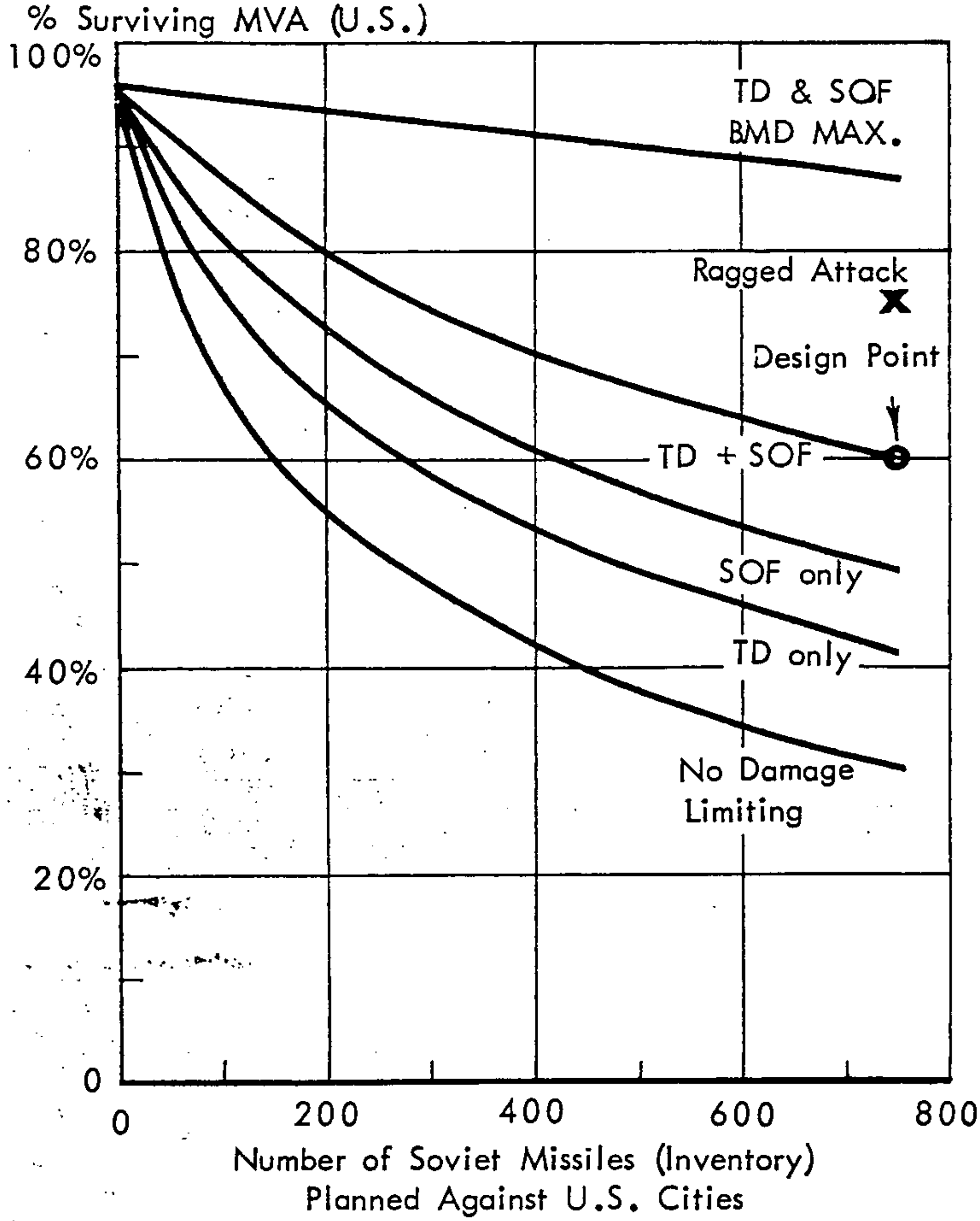

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FIGURE 27

% SURVIVING U. S. MVA vs NUMBER OF SOVIET INVENTORY MISSILES PLANNED AGAINST U. S. CITIES

Soviet Inventory

500 targetable plus 250 non-targetable missiles. The latter are always reserved for use against U/I targets -- all attack sizes below 250 missiles are made up of these missiles, and they are all used (plus targetable missiles) for larger attacks.

3 missiles/aim point.

Reliability = 0.8.

U. S. spends $28.1 billion. Optimum allocation within this budget for Soviet threat described above provides for 60% U. S. MVA surviving. The $28.1 billion is sub-optimized among CD, BMD, TBD, and SOF as described in Figures 2, 4, 5, and 13. The allocation is as follows:

CD:	$5.8 B	(Full Fallout Shelter Program -- but has no effect on MVA).
BMD:	$14.3 B	(25 Target Areas Defended).
TBD:	$0.6 B	(Interlocked with BMD).
SOF:	$7.4 B	(About 1000 MINUTEMAN in inventory for attack of Soviet missile sites. This is exclusive of MINUTEMAN for other purposes). U. S. SOF has a P_k = .6 against Soviet sites.

Notes

(1) "TD only" curve represents a case in which U. S. SOF does not operate on Soviet missiles planned for U. S. cities, i.e. Soviets pre-empt against U. S. cities.

(2) "SOF only" curve represents the case where BMD/TBD is completely ineffective.

(3) "TD and SOF" curve represents the case in which both TD and SOF operate as expected against attacks optimized for maximum U. S. MVA destroyed.

(4) For this Figure and Figure 28: When less than the full inventory is planned against cities, it is assumed that the same <u>fraction</u> of total available forces are used against cities before or after SOF attack. I.e., target categories of missiles are not changed for those missiles surviving SOF attack. Changes after SOF attack in the fraction allocated to cities can be considered "as if" they had "preplanned" the new fraction.

(5) "TD & SOF, BMD Maximum" curve represents the case of attacks against the defended area in order of MVA value despite the fact that these high priority targets are defended (i.e., the attacker is willing to pay the price). It denotes an upper limit of possible effectiveness of a BMD system.

(6) "Ragged Attack" mark denotes damage from attack assuming: (1) Soviets cannot retarget after disruption by U. S. SOF; and (2) Targetable and non-targetable Soviet missiles are randomly distributed among U. S. targets -- i.e., high worth targets are attacked by both Soviet targetable missiles and non-targetable missiles. The utility of U. S. SOF is, of course, greater for the case of a "ragged" Soviet retaliatory strike. The

"expected" return Soviet attack would probably be somewhere between the "ragged" attack and the "re-targeted" attack shown in the curves.

Basic Points

(1) A damage limiting capability can make a difference of up to 55% or 60% in the amount of U. S. MVA surviving an attack by the entire Soviet inventory postulated.

(2) If only half of the Soviet inventory is used against U. S. cities, a damage limiting capability can make a difference of up to 50% in the percent of U. S. MVA surviving.

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Figure 28

% Surviving U.S. Population vs Number of Soviet (Inventory) Missiles Against U.S. Cities

Soviet Inventory : 500 Targetable plus 250 Non-targetable Missiles
Soviet Reliability = 0.8
3 Missiles/Aim Point

U.S. Allocates $28.1 Billion for 60% Surviving MVA, 69% Surviving Population

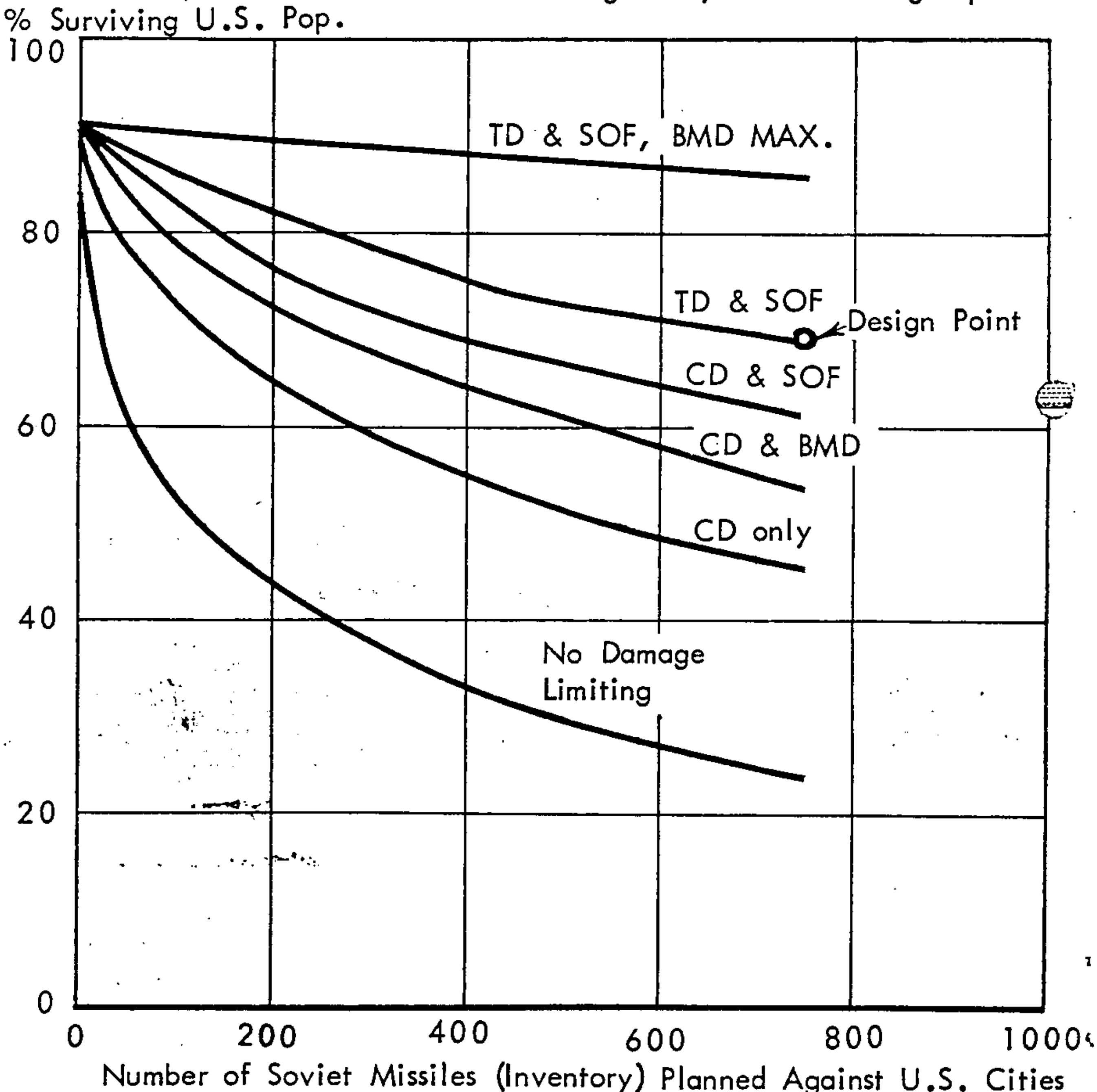

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FIGURE 28

% SURVIVING U. S. POPULATION vs NUMBER SOVIET INVENTORY MISSILES PLANNED AGAINST U. S. CITIES

Same as Figure 27 except for U. S. Population rather than MVA.

Basic Points

(1) The figure shows the large effect of a full fallout shelter program -- saves about 22% of the population for a wide range of attacks.

(2) CD operates in reducing fatalities from both the collateral military attack and the U/I attack.

(3) The effects of BMD and SOF beyond those of CD only are shown separately. BMD provides an incremental saving over CD alone of about 10%. SOF provides an incremental saving over CD alone of about 15%.

(4) Design point is for the full Soviet inventory used against U. S. U/I targets. If the Soviets were to use less, more of the U. S. population survives: 69% survive at the design point of 750 missiles but 75% if they plan to use only 400 missiles against U/I targets.

(5) If all damage limiting measures are effective, the increase in the number of people saved is about 45% of the population if Soviets attack in an optimum fashion. If Soviet attack concentrates on the defended area, up to 62% additional could be saved. (A total of 86% surviving).

Figure 29

% Surviving Soviet MVA vs Number of U. S. Missiles(Inventory)- Attacking Soviet Cities

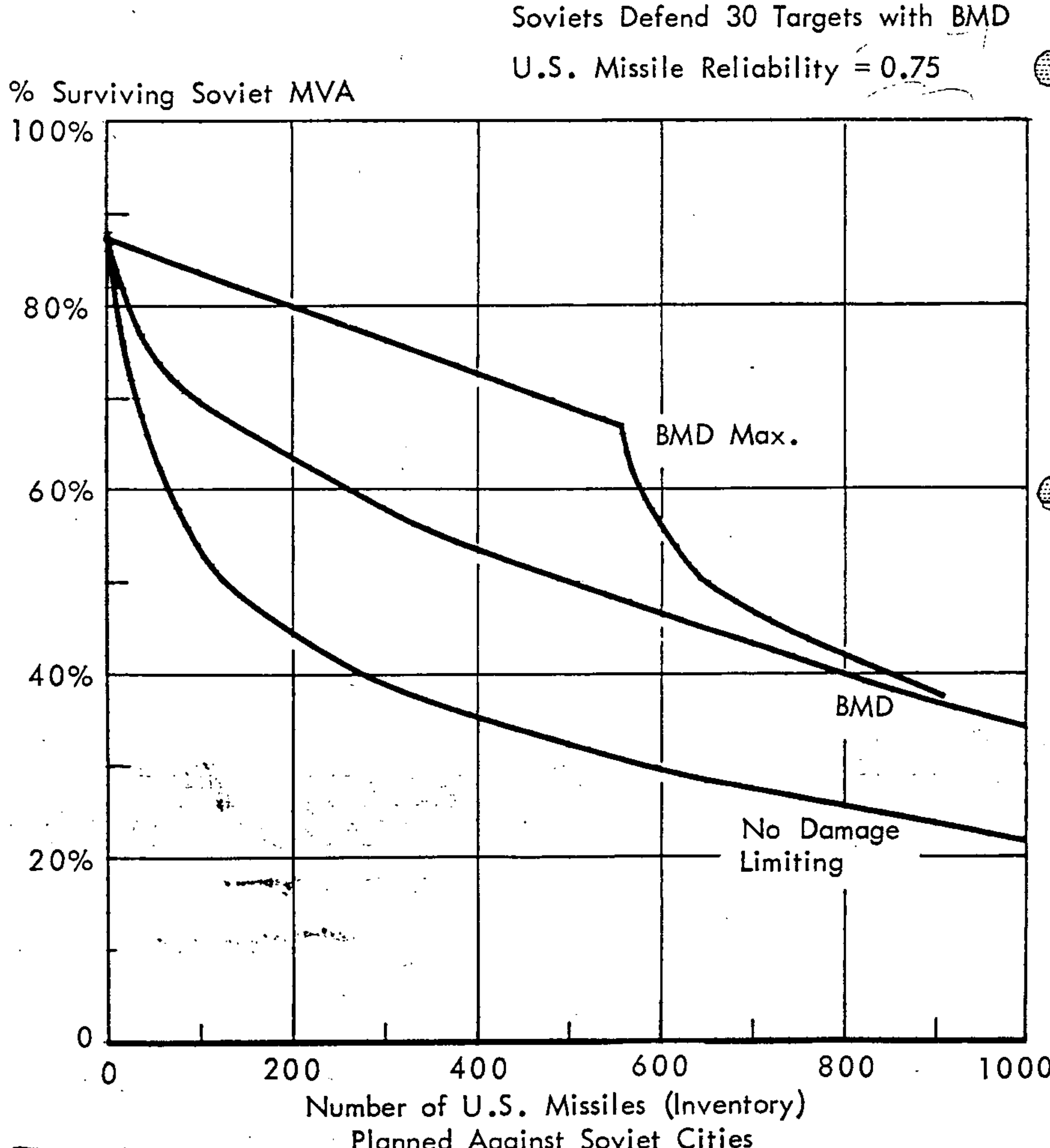

FIGURE 29

% SURVIVING SOVIET MVA vs NUMBER OF U. S. MISSILES ATTACKING SOVIET CITIES

Soviets spend $16.5 billion on BMD (30 target areas defended), nothing on SOF, as described on Figure 17.

Notes

(1) No damage limiting curve is a reference line for no allocations to damage limiting. It also applies for the case where Soviet BMD does not work.

(2) BMD curve represents effect of BMD where U. S. attacks in manner to maximize MVA damage.

(3) BMD maximum curve represents case of attacks first against the defended area in order of MVA value. It denotes an upper limit of possible effectiveness of a BMD system. The curve breaks and falls off after the attacker has paid the price for the defended area and attacks the undefended region.

(4) Soviet SOF is allocated no money for damage limiting. (See Figure 21).

Basic Point

A damage limiting capability can make a difference of about 20% to 40% in the amount of Soviet MVA surviving an attack of 200 to 700 U. S. missiles.

GENERAL OBSERVATIONS ON DAMAGE LIMITING

A. U. S.

The following general statements may be made about suballocations to the various means of limiting damage.

FALLOUT SHELTER PROGRAM (U. S.)

The first $5.8 billion on U. S. damage limiting is best spent on a full-fallout shelter program. This point will be elaborated below.

BALLISTIC MISSILE DEFENSE AND BLAST SHELTERS (U. S.)

BMD is regarded as the charging of a price in missiles for an exclusion area; i.e., an attacker, to be sure of destroying a defended target, must send in the number of missiles decided upon by the defender as the price of the target. The attacker's best option, then, is to attack in the undefended region until the expected damage per missile there is less than the expected damage per missile in the defended area. The modified Prim-Read model used here commits interceptors in such a way that a constant expected damage per missile prevails for all defended targets and all attacking missiles. Empirically, it has been found when BMD is optimized, this expected MVA damage per missile in the defended region is nearly independent of the number of targets defended, and, in fact, is approximately .055% of total U. S. MVA capacity. Thus, a respectable BMD model for the U. S. is contained in the statement: "Set the expected kill of a missile in the defended area equal to .055% of total MVA capacity".

Beyond a Full Fallout Shelter program, Civil Defense (blast shelters) has about the same utility per dollar in saving population as BMD (as may be seen from Figure 5). Since BMD also saves industry, terminal defense expenditures, after $5.8 billion for a Full Fallout Shelter program, would be best made on BMD. This conclusion is independent of the size of the enemy attack, for, since the curves in Figure 2 are roughly parallel, BMD has the same incremental effectiveness per dollar regardless of the size of the attacking force.

Other calculations, not included here, suggest that the possibility of time saturation of BMD does not change the design of a deployed system. Time saturation may be thought of as placing an upper limit on the price in missiles that can be charged for a target.

TERMINAL BOMBER DEFENSE (U. S.)

The relatively small cost of TBD (5% - 10% of BMD cost) brings a large return in % Surviving Population and MVA as Figure 6 indicates. However, for both to be effective, TBD (terminal bomber defense) must be interlocked with BMD. When the defense charges a high price in missiles for a target, the target becomes lucrative to attack by other means. TBD guards against this possibility, and, when under the "BMD umbrella", TBD is insured against defense suppression by missile attack for bomber penetration.

The optimum combination of BMD and TBD (i.e., the point at which an incremental dollar spent on either brings the same increase in % Surviving) is consistent with the point at which a bomber force is excluded from the defended region. Bomber exclusion occurs when it is to the attacker's benefit to replace missiles planned for the undefended region with bombers, and send the missiles instead of the bombers to the defended region. For planning purposes, when confronted with interlocked BMD/TBD, the attacker's best option is a pure missile force against Urban/Industrial targets. That is, with defense, a pure missile force is superior to a mixed bomber-missile force which had the same damage potential in the undefended case.

TERMINAL DEFENSE (U. S.)

When CD, BMD, and TBD have been appropriately combined, it still remains very costly to attain high levels of surviving population and industry (though less costly than by means of any of these three alone). The fact that it is increasingly expensive to negate the effects of large attacks by means of Terminal Defense alone suggests the use of Strategic Offensive Forces to diminish the size of the U/I attack.

STRATEGIC OFFENSIVE FORCES (U. S.)

In combination with terminal defense, SOF shows good utility against hardened Soviet missile sites. The optimum programming ratio of reliable U. S. missiles per Soviet aim point -- optimum in the sense of allocation of money between SOF and TD -- varies with the "% Surviving". For certain cases it can be as high as 4:1. This means 1-1/3 reliable missiles per Soviet missile if the Soviets deploy 3 missiles per site or aim point. If the Soviets do better planning -- 1 missile per aim point -- the ratio on a missile to missile basis varies up to about 3:1. Note: In considering programming ratios, it is useful to keep in mind the constraint that one might also like to maintain more aim points than the enemy has missiles to avoid his getting a 1:1 programming ratio (or better) for his own SOF operations.

The upper limits (at higher "% Surviving") of these programming ratios depend -- not only on the decreasing utility of larger ratios -- but on the fact that forces not targetable by SOF (ICBM's not located, SLBM's, etc.) must be negated by terminal defense.

GENERAL REMARKS (U. S.)

It is significant to note that each means of damage limiting considered has a role -- none are excluded on the basis of a comparison of the relative utility for investment. Combinations of measures have been found cheaper than any one by itself. The optimization process focuses on those combinations which achieve given results at least investment. However, non-optimum combinations may be necessary, or useful, under certain constraints. The analysis also provides a framework with which to evaluate new possibilities for limiting damage. That is, other systems can be compared with the cost of terminal defense to negate a missile. As with each of the measures considered individually, the optimized solutions (combinations) also show decreasing marginal utility for higher levels of surviving MVA and population.

B. SOVIET DAMAGE LIMITING

Applying the same methods of analysis -- or optimization process -- to the Soviet Union, the following general statements can be made about suballocations to ~~the~~ various means of limiting damage:

FALLOUT SHELTER PROGRAM (U. S. S. R.)

Fallout shelters are very effective for an already dispersed population. As in the U. S., moderate fallout shelter programs show great utility. No data were available on the variety of CD programs and costs as used for the U. S., so that it was not possible to develop a rigorous optimization between CD and BMD for saving lives.

BALLISTIC MISSILE DEFENSE (U. S. S. R.)

Because of its concentration, Soviet MVA is more easily defended than the U. S. MVA against small or medium attacks. However, for large U. S. attacks this concentration works to the disadvantage of the Soviets.

STRATEGIC OFFENSIVE FORCES (U. S. S. R.)

For a Soviet cost of $25 million per reliable missile, with a $P_K \leq 0.6$, and with a considerable non-targetable problem (POLARIS) and an "empty holes problem" (not all MINUTEMAN are planned against Soviet cities), Soviet SOF is never an optimal means of limiting Soviet damage. (See Figures 19 to 21).

This behavior is quite different than in the U. S. case. In both instances, one is comparing the cost of destroying a missile before launch, with the cost of negating its effects at the terminal end. The latter depends on: (1) the size of the attacking missile -- the Soviet missiles are larger; and (2) the concentrations of target worth -- Soviet MVA is more concentrated and easier to defend from small to medium U. S. attacks.

The utility of SOF depends on: (1) the cost per reliable missile; (2) the kill probability, P_K, against hardened sites; and (3) the number of enemy missiles deployed at each site. It costs the Soviets about 2 times as much per missile destroyed as the U. S. But terminal defense costs are less. For example, for 60% MVA surviving (at higher levels differences in collateral damage and other factors begin to dominate), the U. S. cost is $140 million to negate a missile and the Soviet cost is $75 million -- about one-half as much for the Soviets as for the U. S. Both factors, high Soviet SOF cost and relative BMD efficiency, make Soviet SOF an unattractive option. In addition, this is reinforced by the existence of a considerable POLARIS force, not targetable by Soviet SOF.

GENERAL REMARKS (U. S. S. R.)

Optimal Soviet damage limiting can be seen as (1) a full fallout shelter program, and (2) for larger budgets -- ballistic missile defense, but no SOF capability against hardened MINUTEMAN sites.

U. S. - SOVIET DEFENSE/OFFENSE COMPARISONS

The attacker's reaction to and the defender's maintenance of a given damage limiting capability can be examined in terms of the defense/offense cost ratio. This ratio represents the ratio of the cost to the defense of maintaining a given level surviving to the cost of an increased threat by the attacker.

Asymmetries exist in the distributions of MVA and population in the two countries: (1) Soviet MVA is more concentrated than U. S. MVA and is easier to defend by BMD, (2) Soviet population, however, is more dispersed than is U. S., and the large U. S. suburban populations are more vulnerable to fallout. Equal terminal defense (CD, BMD) measures on both sides tend toward equalization of these effects to some degree. That is, the discrepancy is greater with no defense than with defense. (See Figures 25 and 26).

Comparison of defense/offense cost ratios show that those for the Soviets are somewhat higher than those for the U. S. (Figures 22, 23, 24), even though the damage per unit cost of attack is less for the U. S. than for the Soviets. (U. S. combination of POLARIS A-3, B-3 and a few MINUTEMAN probably average to about $30 million/reliable attacking missile carrying the equivalent of 1 MT; Soviet cost per missile is about the same -- $25 million per reliable attacking missile. Each Soviet missile carries the equivalent of 5 MT -- the Soviets pay for this low cost of deployment; their force is more vulnerable.)

The higher defense/offense cost ratios for the Soviets are due to lack of utility of a Soviet SOF capability. This utility is poor even if the U. S. used only targetable MINUTEMAN forces instead of POLARIS for Soviet U/I attacks. (See Figures 19 to 21). It is also due to poor Soviet planning. The Soviets could raise the defense/offense cost ratio for the U. S. by making U. S. SOF less lucrative by the following measures:

(1) Deploying Soviet missiles at one missile per aim point.

(2) Building a MINUTEMAN type missile -- for a given investment this increases the number of aim points over that inherent in the use of larger missiles.

(3) Making a large fraction of their force non-targetable by U. S. SOF (SLBM's, etc.).

The defense/offense cost ratio depends most critically on: (1) the "% Surviving" -- for higher % Surviving the ratio is higher; (2) the quality of planning on both sides; and (3) the possible scenarios of a nuclear war. The relatively poor utility of Soviet SOF -- given the U. S. deployment of dispersed MINUTEMAN missiles and non-targetable POLARIS missiles -- has a direct bearing on the likelihood of certain scenarios. This poor utility reduces the likelihood of Soviet pre-emption against U. S. forces in a disarming attempt in that the likelihood that the Soviets will make a serious attempt to deploy a damage limiting force in the first place is greatly reduced.

GENERAL PICTURE OF DAMAGE LIMITING BY THE U. S. AND BY THE U. S. S. R.

Depending on the relative levels of effort on damage limiting by the defense and "damage inflicting" by the offense, the amount of industry and population surviving nuclear attacks can be raised and maintained at levels above the "no defense" posture. For the United States, there is the potential for raising the levels from around 25% - 30% surviving up to about 80% surviving for both industry and population, allowing for present indications of poor planning on the part of the Soviets. On the Soviet side, there is the potential for raising the levels from about 40% surviving up to 80% surviving for population and from about 30% surviving to 60% surviving industrial capacity. The lower bounds are set by concentrated U/I attacks with no defense measures, the upper bounds by unfavorable cost ratios. It is to be noted that this ratio is not entirely the option of the defense. It represents an interaction between the two sides. Higher ratios can only be attained by a permissive or constrained offense. Reaction to a given damage limiting capability can be considered in terms of the defense/offense cost ratio.

In the context of this study, the overall decisions on the allocations of resources to limiting damage are reduced to considering the size of the threat and to how much total money is to be allocated against it. With curves of utility versus cost, this is an iterative process. One tries a budget, examines the utility, and then examines the differences in utility against the differences in cost for other budgets. The final decision as to the total budget is a matter of judgment. The subdivision of this budget is then a technical sub-optimization problem of the kind treated in this study.

GLOSSARY

AP: Aim point; missile sites which contain one or more missiles.

B: Billions.

BMD: Ballistic Missile Defense.

CD: Civil Defense.

DT: Defended Targets; i.e., defended with Ballistic Missile Defense.

FFO: Full Fallout Shelter Program.

M: Millions.

MVA: Manufacturing Value Added (a measure of industrial capacity).

P_A: Area Penetration Probability (of bombers).

PF: Protection Factor, radiation. Ratio of exterior dose to interior dose.

Pop: Population.

Rel: Reliability.

SOF: Strategic Offensive Forces.

$SRRP_A$: Bomber Survivability X Readiness X Reliability X Area Penetration Probability.

SSP_k: Single Shot Kill Probability.

TBD: Terminal Bomber Defense.

TD: Terminal Defense (Combinations of Civil Defense, Ballistic Missile Defense, and Terminal Bomber Defense.

U/I: Urban/Industrial.

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