Section 7

A HYPOTHETICAL SYSTEM ARCHITECTURE

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Most analysts of boost-phase BMD assume that midcourse and terminal BMDs will augment the boost-phase layer. This section assembles a hypothetical layered defense system ***in toto.*** This system is pure/y ***illustrative,*** taking current BMD concepts at their face value and conveying a concrete image of the defensive architectures analysts apparently have in mind when they speak of nationwide defense. Obviously there are many choices for such a "strawman " system. The particular system described below was chosen for its illustrative value and not because it represents some "most plausible" alternative. It would be meaningless to suggest a "front runner" in the present state of study and technology development. Rather, the purpose of this example is to show how the layers interact and to indicate the overall scale of the deployments contemplated, without implying that anything remotely like it ever could or would be built.

A defense with several layers presents the offensive planner with some of the variety of problems that afflicts the BMD designer, who never knows in advance which attack tactic or countermeasure the offense will choose and must include responses to all of them in the system design. Layered defense forces the offense not only to develop responses to all the layers, but to develop responses that can be accomplished simultaneously. Thus, for example, the method chosen to avoid boost-phase intercept must not prevent deployment of lightweight midcourse decoys. The synergistic effect of the several layers obviously works strongly in the defense's favor.

Nonetheless, one must compare the performance of a three-tiered defense to the performance of a two-tiered defense of the same cost. Thus it should be no surprise if a $200 billion system with boost (and possibly even post-boost), midcourse, and terminal layers performs better than a $50 billion system with no boost phase layer. The correct questions are whether the additional $150 billion is worth the extra performance, and whether spending the $150 billion on more terminal and midcourse defense would in fact be a better investment.

Occasionally one sees a simplified leakage calculus applied to layered defense. The calculus assigns a "leakage" of, say, 25 percent (0.25) to the boost phase layer, 15 percent to the midcourse layer, and 10 percent to the reentry layer, deducing an "overall leakage" of 0.4 percent on the basis of the equation $(0.25)\times(0.15)\times(0.10) = 0.004$. Though the term leakage can be defined so that this calculus holds, the result actually bears little relation to the number of targets preserved by the defense. For one thing, a given defensive layer does not have an associated leakage ***fraction*** independent of attack size: the leakage fraction for each layer usually increases with attack size, most obviously (but not only) when the defensive arsenal becomes saturated. Second, the performance levels of the individual layers are not independent. For example, if the midcourse layer's interceptor arsenal is sized to handle only 25 percent of the attack, and the boost-phase layer works poorly and in fact allows 50 percent of the attack through, the midcourse layer obviously cannot display the same fractional efficiency against the attack of double the expected intensity. Conversely, improvements in one layer might improve performance of another: effective boost-phase or midcourse layers might force the offense to abandon the highly structured "laydowns" of RVs in space and time that limit a terminal layer's effectiveness. Third, the raw number or fraction of leaking RVs does not indicate the number or fraction of targets destroyed because of the tactics of preferential offense and defense. For these reasons, the leakage calculus is not a helpful way to encapsulate layered defense performance.

7.1 SYSTEM DESCRIPTION

The system design described below takes literally the goal of comprehensive nationwide defense. It seeks the capability (at least on paper) to engage all attacking Soviet missiles, whether targeted at cities, U.S. silos, or other military installations. Clearly the precise numbers and kinds of components in this description can be adjusted to suit any set of assumptions. The point of this description is merely to convey the flavor of these massive architectures. Most assumptions are favorable to the defense.

Suppose that at some time in the future the Soviet ICBM arsenal still consists of 1,400 boosters, as it does today. For simplicity, suppose further that each booster is an MX-sized solid propellant missile carrying 10 RVs and that all silos are located in one large region of the U.S.S.R. The boosters are not specially shielded against lasers, but some care in their design has given them an effective hardness of 10 kJ/cm^2, and they are further spun during ascent. Each booster carries a small number of decoys, but their small number is offset by the decoys' high fidelity. Each RV is accompanied by 9 lightweight infrared replicas and 1 high altitude reentry decoy. (This is a very modest penetration aid loading. One can assume larger numbers with perhaps poorer fidelity, chaff and aerosols, etc.)

The hypothetical U.S. defense system comprises both HF chemical laser battle stations and x-ray laser battle stations for boost-phase intercept, land-based midcourse interceptors carrying LWIR homing vehicles (the so-called "Overlay"), and land-based high-endoatmospheric homing interceptors with non-nuclear warheads for reentry intercept.

Table 7.1.—Hypothetical Future U.S. Defense Designed for Nationwide Protection Against Hypothetical Future Soviet Offense

U.S. Defense	Soviet Offense
5 warning satellites	1,400 MX-like ICBMs deployed in one region
180 HF laser satellites	10 RVs per ICBM
180 laser radars	9 midcourse decoys per RV
900 x-ray laser satellites	1 reentry decoy per RV
900 MWIR trackers	
28,000 midcourse intercept vehicles and boosters	
20 LWIR satellites	
75 radars	
140,000 terminal non-nuclear interceptors	
25 aircraft with LWIR sensors	

SOURCE: Author.

The HF chemical laser system resembles that described in Section 3.1, except that it has only five 20 MW lasers at each position in the 32-position constellation, for a worldwide total of 160. At a range of 2 Mm, a laser must dwell on each spinning booster for 5 seconds, so each laser at this range can handle 30 simultaneously launched boosters if defense begins 30 sec into the 180 sec boost phase of an MX-like booster. The five lasers overhead the Soviet silos at any one time can therefore only handle 150 of the 1,400 Soviet ICBMs. For small Soviet attacks, however, this non-nuclear boost-phase layer suffices.

For a large-scale Soviet attack, the United States deploys in addition a nuclear boost-phase system of x-ray lasers. A "perfect" laser with characteristics such as those derived in Section 3.3 can intercept ideally about 50 boosters at 4 Mm range. Therefore 28 lasers need to be in position over the Soviet silos at any time to handle a massive launch, giving a worldwide total of 900 (absentee ratio 32).

Warning for the boost-phase system is provided by MWIR warning satellites in synchronous or supersynchronous orbits. Also, each of the 160 HF laser battle stations has an MWIR telescope with 4 m mirror and an ultraviolet or visible ladar with 2 m mirror for pointing. Each x-ray laser is accompanied by an MWIR telescope tracker with 1 m mirror.

The 1,400 Soviet boosters carry 14,000 RVs, 126,000 midcourse decoys, and 14,000 reentry decoys. The United States assumes that only 10 percent of the boosters will survive the boost phase defense, so the midcourse tier needs to face 1,400 RVs and 12,600 midcourse decoys. The midcourse interceptors are given extremely long range, so only two bases are needed to cover the entire United States. However, each base must be prepared to absorb the entire attack, since the Soviets could target one half of the country more heavily than the other. Therefore the United States needs 14,000 midcourse interceptors at each base, for a total of 28,000 interceptors. A constellation of 20 satellites with large LWIR sensors provide long-range acquisition and target assignment to these interceptors.

The United States next estimates that 90 percent of the RVs that enter the midcourse layer will be successfully intercepted. The terminal defense must handle 140 RVs plus 140 reentry decoys.[1] The reentry decoys are, by assumption, completely faithful in mimicking the signatures of RVs as seen by ground-based radars and aircraft-borne infrared sensors during early reentry—large decoy numbers have been sacrificed for this high fidelity. If the U.S. defense takes literally its charge of nationwide defense, it must be prepared to make 280 intercepts anywhere in the country.

[1] The number of reentry decoys the terminal system must face actually depends on whether the decoys fool the midcourse as well as the terminal system's sensors and on whether the terminal and midcourse layers cooperate in discrimination. Suppose first that the reentry decoys look like RVs (and therefore also like midcourse decoys) to the midcourse layer's sensor. Then the midcourse layer will Intercept 90 percent of them (more midcourse interceptors must be bought to do this). If, on the other hand, the midcourse layer correctly identifies the reentry decoys as non-lethal objects, it might (a) not intercept them, requiring the terminal layer to plan to face 140 RVs plus 1400 reentry decoys, increasing enormously the required arsenal of terminal interceptors; (b) intercept them, in which case a reentry decoy is a perfect midcourse decoy, making possible a new threat–large numbers of midcourse decoys that look like reentry decoys rather than RVs; (c) radio the information, object-by-object, to the terminal defense fields.

Each terminal defense site consists of a phased-array radar and a number of high altitude non-nuclear interceptors. Additional target acquisition support is provided by a fleet of aircraft patrolling the U.S. periphery, carrying LWIR sensors. Each radar has a radius of action of over 200 km, so 75 or so cover the entire United States. However, an interceptor only covers an area about 50 km in radius. Since the area of the United States is about 8 million square km, over 1,000 interceptor sites would be needed for nationwide coverage. Should the defense have to reckon with intensive Soviet attack on some regions and no attack on others? Clearly, yes. But equipping each interceptor site to handle all 280 objects passing through the first two layers would require buying 280,000 interceptors! The defense would need to buy this many interceptors if it wanted to claim the literal capability to engage ***all*** Soviet RVs, ***no matter*** where they landed. Suppose, then, that the United States hopes for a more evenly distributed Soviet attack and deploys just half of the arsenal needed for complete coverage— 140 interceptors per region. One radar might not suffice to handle all the RV traffic in its sector if the Soviets attack some sectors preferentially, but the United States nonetheless buys just 75 radars. Five aircraft on patrol at all times requires a backup fleet totalling perhaps 25.

Table 7.1 summarizes the offensive and defensive deployments.

7.2 ASSESSMENT

It is obviously not possible to assess the performance of a system, such as the hypothetical layered defense described above, whose components are not (and in many cases cannot be) designed today, much less assembled in an overall architecture. It is nonetheless worth sketching, in the illustrative spirit of this section, the issues that would require analysis if anything resembling Table 7.1 were ever proposed for deployment.

The first issue concerns the cost of the improvements to the system needed to offset growth in the Soviet ICBM arsenal—that is, the cost exchange ratio. The number of defensive weapons is proportional to the number of Soviet ICBMs. If the Soviets were to double the size of their ICBM arsenal, the United States would need to double the number of its x-ray lasers and interceptor missiles. (The number of sensors would generally have to increase also, though perhaps not in proportion to the Soviet buildup. The number of HF lasers could remain the same if the United States continued to intend to use this non-nuclear boost-phase layer to engage only Soviet attacks of 150 boosters or less.) Comparison of the two columns of Table 7.1 indicates that an arms race of Soviet offense and U.S. defense seems certain to favor the Soviet side greatly.

A second issue concerns the huge inventories of midcourse and reentry interceptors needed for nationwide defense. The arsenal of reentry interceptors shown in Table 7.1 is in fact only half the size needed for literally complete nationwide coverage, as remarked above. The cause of these large interceptor inventories–besides the obvious presence of decoys–is twofold: first, the low leakage sought by the defense precludes preferential defense, the tactic that makes silo defense so much more economical; and second, the limited coverage of each interceptor battery makes preferential ***offense*** possible for the attacker. The goal of nationwide low-leakage defense therefore forces the BMD system to forfeit the two sources of leverage that have historically impelled BMD towards the technically modest mission of defending compact silo deployments to relatively low survival levels.

Soviet countermeasures–besides straightforward buildup of ICBMs—is a third issue. The particular boost-phase layers described above are susceptible in varying degrees to all of the countermeasures described in Section 5, and the midcourse and reentry layers to their respective sets of countermeasures.

Defensive coverage against submarine-launched ballistic missiles (SLBMs) is a fourth issue. The boost-phase layers can intercept SLBMs launched from all points on the globe. Though the average range from laser satellite to booster is larger at equatorial and polar latitudes than at the mid-latitudes where Soviet ICBMs are located, the number of SLBMs that could be launched in a short time from each ocean area is also much smaller than the huge number of ICBMs that could lift off simultaneously from the U.S.S.R. Even the chemical laser deployment alone might suffice for boost-phase coverage of SLBMs. The midcourse and reentry layers, however, would in general not perform as well against SLBMs as against ICBMs. SLBM trajectories present bad viewing angles to the midcourse layer's LWIR sensors, and the short timeline limits interceptor coverage. The reentry layer would need to be augmented with more airborne sensors and more radars (or radar faces) to cover attack from the ocean. In general, then, a layered system optimized for ICBM defense could not necessarily handle SLBMs as well.