

## Re: the National Academies of Science Report, “[Making Sense of Ballistic Missile Defense...](#)”

Comments by Richard L. Garwin, October 1, 2012<sup>1</sup>  
[www.fas.org/RLG/](http://www.fas.org/RLG/)

This is by no means a full assessment of the report, which I believe is necessary and would be salutary. The Report has some useful analyses and observations, but it has major failings. In particular, it ignores from previous assessments interceptors that would be much more effective than the “straw men” it considered. And the midcourse system it advocates is inadequate to the task in radar performance and depends on the perfection of long-sought midcourse discrimination against countermeasures without any indication of how this might be achieved.

The Report did not, in fact, evaluate candidate boost-phase intercept (BPI) systems that have been proposed and that have a possibility of working.

For instance, in my 1999 paper, “[Cooperative Ballistic Missile Defense](#),”<sup>2</sup> I advocated a ground-based interceptor, GBI, with a burnout velocity, BOV, of 8.5 km/s based in Vladivostok and on ships near the coast of North Korea. This is, in fact, more performance than is necessary for that basing and for ICBM launches from anywhere within this small country.

The proposition is stated more clearly in my 2005 paper “[National Missile Defense: Prospects and Problems](#).”<sup>3</sup> That document provides much better graphics and pictures of some inflatable decoys. But it provides also (p. 22) a clear graphic of a 100-s burn-time GBI with a BOV of 8.5 km/s; the GBI is assumed also to be based on special purpose ships converted from obsolete commercial shipping. Solving the long-range missile problem only for North Korea and for a time would be useful, even if the same deployment would be ineffective against Iran. Reducing the burn time to 45 seconds might increase the interceptor gross weight by 20%.

There are some other useful items in my 2005 document, particularly p. 13, a configuration for a conical bomblet to deliver BW agents such as anthrax, which, the NAS BMD Report (p. 2-26<sup>4</sup>) states cannot be countered by midcourse or terminal intercept. Even though the NAS authoring committee defined its task as protecting the

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<sup>1</sup> Provided to the NAS authoring and review committees on September 21, 2012.

<sup>2</sup> <http://www.fas.org/rlg/991117.htm>

<sup>3</sup> <http://www.fas.org/rlg/030605nmdp1.pdf>

<sup>4</sup> “*The sooner this could be done after submunition dispersal, the smaller the volume that would have to be swept but the more vulnerable the sweeper platform would be. Unfortunately, there is no effective volume kill capability other than the detonation of a nuclear weapon.*”

U.S. homeland against nuclear or other WMD attack<sup>5</sup>, this strong conclusion of a free ride for bomblet-delivered BW nowhere figures in its actual Conclusions or Summary.

Adding to the puzzle of the Committee’s neglect of existing, high-quality and carefully reviewed assessments of boost-phase intercept is its failure to consider the detailed calculations of the [2004 American Physical Society Study on Boost-Phase Intercept<sup>6</sup> Systems for National Missile Defense](#), which considered in detail interceptors I-2, I-4, and I-5, as shown in the table:

Table 16.5. Interceptor Models Used in the Study

Model	Burnout		Liftoff Mass (tonne)	Number of Stages
	Velocity (km/s)	Boost Time (s)		
I-1	1.7	47	1.57	2
I-2	5.0	47	2.26	3
I-3	6.7	75	14.60	2
I-4	6.5	40	16.91	2
I-5	10.0	45	65.60	3

Note: Burnout velocity is that for a vertical trajectory.

The 6.5 and 10.0 km/s interceptors were highly capable against liquid-fueled ICBMs and even under some circumstances against high-performance solid-fueled missiles with 180s burntime. But the NAS Committee did not provide a technical assessment with these interceptors. Four Committee members were members of the 2004 APS Study group; if they have recognized some flaw in their previous analysis, any correction should have been provided frankly in the NAS report; if not, these interceptors should have been evaluated as part of the charge to the NAS Committee. Note that the reduction in Boost Time from 75 to 40s at similar BOV forces an increase of Liftoff Mass of only 15%.

Intercept performance of these two interceptors is indicated by these quotations from the text of the 2004 APS Study Report:

(p. S82:) ***“Defense against liquid-propellant ICBM model L***  
*“The 6.5-km/s interceptor could provide about 40 s of decision time, if based at sea. If it were ground-based in Vladivostock, the decision time would be about 60 s.”*

(p. S82:) ***“Defense against solid-propellant ICBM model S1***  
*“The lower-left panel of Figure 5.10 reveals that even the 6.5-km/s interceptor could be used to defend Boston only if it were fired very close to the coast with zero decision time. The giant 10-km/s interceptor (Fig. 5.10, lower right) could be used with about 30 s of decision time. Deploying such a large missile at sea could*

<sup>5</sup>“(1) protection of the U.S. homeland against nuclear weapons, other weapons of mass destruction (WMD), or conventional ballistic missile attacks” (p. S-1).

<sup>6</sup>[http://rmp.aps.org/pdf/RMP/v76/i3/pS1\\_1](http://rmp.aps.org/pdf/RMP/v76/i3/pS1_1)

*present a challenge, but it might be possible to base it in Vladivostok, which would permit the decision time to be increased by about five seconds.”*

In a May 3, 2012 Moscow brief, MDA identifies the North Korean threat as the Taepo-Dong 2, tested 2006, 2009, and 2012, which has a 500s burn time<sup>7</sup>.

Both the 2004 APS Study and the 2012 NAS study adopt the criterion, “*Intercept must take place not just before burnout of the threat booster but before it reaches a velocity that can threaten any area to be protected.*” (e.g., p. 2-29 of the NAS report). But the Terms of Reference (p. A-1 of the NAS Study simply requests that the Study “*evaluate*” “*(i) shortfall from intercepts;*” and “*(k) effectiveness against countermeasures;*” The Committee itself seems to have assumed that substituting a detonation at a random point on the territory of the USA or its allies for a planned detonation on a target city would have no deterrent or protective effect, despite a likely 100-fold reduction in fatalities. Contrast this absolutist, self-imposed requirement for no shortfall on the “protected” territories with the effectiveness against countermeasures that is simply assumed by the Study group.

Furthermore, I question the need for “decision time” of 5, 10, or 30 seconds, before firing the interceptor. It is physically impossible for these interceptors to shoot down an airliner, and there is more than a minute after launch for a decision to disable the homing system on the interceptor if the command authorities wish to avoid destroying a space launch.

Because Iran is far larger than North Korea, boost-phase intercept with ground-launched interceptors is much more difficult. But it is not beyond reason to base such interceptors “unconventionally” in Turkmenistan, for instance, or in eastern Turkey.

Two other major problems with the Report:

1. The Report argues that the only effective BMD against long-range missiles is midcourse intercept, with shoot-look-shoot (SLS). It also states, forcefully, that this is totally dependent on midcourse discrimination and also that no one in BMD was able to tell the Committee or walk them through the results from various experiments sponsored by BMD and its predecessors<sup>8</sup>.

The Committee also dismisses the unclassified summary of a [1999 National Intelligence Estimate](#)<sup>9</sup> that by the time nascent ICBM countries such as North Korea or Iran deploy

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<sup>7</sup> Although an ICBM version of this space launcher might have a third stage with shorter burn time, for a total of perhaps 350 seconds. (Footnote added October 1, 2012).

<sup>8</sup> “*Yet the committee could not find anyone at MDA who could show it those data or explain them, let alone the data from ground-based interceptor flight tests.*” (p. S-9)

<sup>9</sup> “Foreign Missile Developments and the Ballistic Missile Threat to the United States Through 2015,” National Intelligence Council (September 1999) available at <http://www.fas.org/irp/threat/missile/nie99msl.htm>.

their first missiles, they would be able to have simple countermeasures such as balloon decoys, oriented warheads, and the like:

- o *"Many countries, such as North Korea, Iran, and Iraq probably would rely initially on readily available technology-- including separating RVs, spin-stabilized RVs, RV reorientation, radar absorbing material (RAM), booster fragmentation, low-power jammers, chaff, and simple (balloon) decoys-- to develop penetration aids and countermeasures.*
- o *"These countries could develop countermeasures based on these technologies by the time they flight test their missiles."*

The question of countermeasures is analyzed in great detail in the-year 2000 MIT-UCS document "[Countermeasures](#),"<sup>10</sup> but the Committee makes no technical analysis about this. It repeats only the shibboleth that the U.S. and UK had difficulties with their countermeasures, without noting that these were either traffic or replica countermeasures and not spherical balloons with anti-simulation, as emphasized in the Countermeasures-2000 volume, and that those countermeasures had to be effective against nuclear-armed interceptors.

2. The Report notes that "some" believe that shorter-range missiles fired from ships near U.S. shores could be used to attack coastal cities with nuclear weapons or other WMD, but it does not consider that these ships might be ordinary cargo ships or masquerade as ordinary cargo ships. Indeed, they could be very small ships, of the nature of torpedo boats or even smaller, since they would be single-use ships. And the self-imposed requirement to protect all of U.S. territory means that a defense would fail if some place in Hawaii or Alaska (not necessarily a city) could be attacked with a short-range ballistic missile or even one of the thousands of cruise missiles in the armories of many nations.

Somehow the Committee judges that MDA could be energized to mine the data it already has on midcourse discrimination, and gather new, essential data, and determine the effectiveness and cost of its proposed midcourse discrimination measures. No evidence is provided that this is likely.

Finally, I address some of the radar calculations in the report. I am puzzled by p. 5-20, where the Committee adduces what seems to be a totally unnecessary limitation on the radar, totally extraneous to its power and aperture—a limit which is readily avoided or evaded. For instance, even with a radar with excess aperture and power, the Report argues

*"Without regard to the transmitted waveform, the time required to exchange a pulse with the target at 1,000 km range is equal to twice the range divided by the velocity of light, which is ~ 7 ms, plus an allowance for reception of the entire echo, totaling ~ 8 ms. For example, if integration of 10 pulses for acquisition and*

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<sup>10</sup> [http://www.ucsusa.org/assets/documents/nwgs/cm\\_all.pdf](http://www.ucsusa.org/assets/documents/nwgs/cm_all.pdf)

*tracking were necessary, a beam dwell of approximately 80 ms at 1,000-km target range, or 160 ms at 2,000-km target range would be required. Accurate velocity measurement and range-Doppler imaging would typically require a sequence of these 10-pulse dwells over a period of approximately 10 s (for example, 4 dwells at 2.5-s intervals). Thus, each target would consume a nominal 320-640 ms in 10 sec, or 3.2-6.4 percent of the radar's time."*

And if the targets were at 3,000 km, the time per target would be about 1,000 ms, or about 10% of the radar's time.

Except that this limit is entirely unnecessary. A phased-array radar does not need to have a beam dwell on a target until the echo returns. The radar should have a hierarchical mode of operation, in which even small signals define a box in space for each of the targets for discrimination, and then a pulse is launched at each target in turn (or at several targets if they are included in a beam width). Then at the calculated delay time for the echo from each object, the relevant "receive beam" is used as input to the discrimination software for that object. So aside from the amplitude of the returned signal, which is, of course, a fundamental limitation, there is no such limitation due to time delay of the round-trip radar wave.

A second problem is the capability of the radar to detect small echoes from the targets--for instance, the determination of the length of a rounded-nose conical warhead, for which both the nose return and the radar return from a rounded back are very small. However, rather than absolute calculations, one can compare the Committee-proposed radars with the GBR (the ground-based x-band radar previously deemed essential for success of the BMD system). The 1999 plan of the Ballistic Missile Defense Organization included nine such GBRs, each with a power output of about 140 kw and a face area of 384 m<sup>2</sup>, with the purpose of mid-course discrimination. Instead, the Committee proposes a radar consisting of two "stacked" AN/TPY2s, with a combined face area of 18.4 m<sup>2</sup> and a total power output of about 160 kW. For discrimination, the performance of two radars is equal for a triple product of area\*power\*gain, where the gain at x-band is in turn proportional to the area. So the figure of merit (FOM) of a stacked AN/TPY-2 relative to a GBR is  $(160*18.4^2)/(140*384^2) = 54170/(20,644,000) = 1/381$ . The range at which the stacked AN/TPY-2 can "see" for discrimination purposes an object of small radar cross section ("RCS") such as the rounded tip of a warhead is proportional to the (1/4)-power of this FOM, so the Committee's radar has an effective range of only about 23% that of the GBR.

Furthermore, if the oriented warhead is fitted with an appropriate metallic-foil conical nose sleeve that would burn off on reentry, the radar return from the nose would be vanishingly small, and discrimination on the basis of RV length would be impossible, even without other countermeasures.

Even for surveillance, and location of the "threat cloud," which is done more capably by lower-frequency radars, the figure of merit of an x-band radar is its power-aperture

product, which for the Committee's radar is 5.5% that of the GBR, corresponding to an effective range only 0.48 that of the GBR.

In short, the Committee acknowledges that its proposed system for mid-course intercept of ICBM-delivered nuclear warheads is totally dependent on midcourse discrimination, for which it provides no technical approach to counter the countermeasures already judged feasible by the 1999 NIE—for instance, spherical aluminized balloons with anti-simulation. It acknowledges that its proposed system has zero capability against bomblet-delivered BW. Furthermore, the Committee-proposed “stacked AN/TPY-2” is inadequate to the task of discriminating oriented conical warheads even in the absence of other countermeasures.

The Report makes several observations that are troubling. For instance, “*Any BMD system would provide some inherent capabilities for defense against accidental or unauthorized launch of a Russian or Chinese missile or, for that matter, one owned by another power.*” This judgment, probably correct, confirms Russian concerns and the need for China to modernize its ICBM force to include MIRVs and countermeasures. It accords with the [testimony of former CIA Director James Woolsey](#)<sup>11</sup> that he would not support the deployment of a ballistic missile defense system that had no capability against Chinese ICBMs, “*Senator Biden asked Secretary Woolsey whether he would favor the deployment of a limited BMD stipulated effective against Iran and North Korea but ineffective against China; Woolsey replied that he would not.*”

In general, though, the NAS report is rife with opinion and lacking in analysis of the standard, for instance, of the 2004 APS Boost-phase Intercept report.

The Report also states, “*Accordingly, great care should be taken by the United States in ensuring that negotiations on space agreements not adversely impact missile defense effectiveness.*” This assumes primacy of missile defense capabilities over other possible national interests—a dubious assumption especially if the missile defense is ineffective.

As a member of all three academies, NAS, NAE, and IOM, and as one who has worked hard for many years on both authoring committees and review committees, I regret that this report was published with such serious deficiencies. It should not be used as the basis of national policy<sup>12</sup>.

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<sup>11</sup> <http://www.fas.org/rlg/9007TEST1.pdf>

<sup>12</sup> Sentence added October 1, 2012. I do not fault the Academies for not responding to this criticism in the nine days since they received it, but believe it important to provide it to public officials and to the public at large while I await the response.