02/06/2013 For the record. The purpose of this post in the Garwin Archive is to document, not to justify, my initial criticism of the National Research Council BMD Committee Report, "Making Sense of Missile Defense." My post of 10/01/2012 was provoked by comments from the House Armed Services Committee that the Report justified the HASC's judgment of the urgent need for an East Coast missile defense site.

I had provided my criticism to the NRC in the hope that a private approach would result in some clarification for me of my understanding of the Report, and I was pleased when I did receive a response from the co-chairs of the Committee, but the pace of the response was not such as to constitute a useful channel for such clarification.

In retrospect, I conclude that it would have been far less trouble for all concerned and ultimately more effective for me simply to have recorded my observations and published them or posted them in the Archive. An example of such an option is the publication by the Arms Control Association of a report by Philip E. Coyle, at https://www.armscontrol.org/act/2013_01-02/Back-to-the-Drawing-Board-The-Need-for-Sound-Science-in-US-Missile-Defense

In this summary, I refer to but I don't quote extensively the very helpful correspondence from David K. Barton, NRC BMD Committee member.

I hope that this additional posting provides those who saw the first one with additional information and documentation.

On 10/01/2012 I posted in the Garwin Archive the item, "Comments by Richard L. Garwin, October 1, 2012, Re: the National Academies of Science Report, 'Making Sense of Ballistic Missile Defense…'", which see[1]. This had been provided to the authoring Committee (the "BMD Committee") on 09/20/2012.

The present document updates those Comments in view of a response from the BMD Committee dated 10/12/2012 and sent to me on 11/01/2012. Unfortunately, that document is labeled "NRC PRIVILEGED INFORMATION//DOCUMENT MAY CONTAIN ITAR/EAR RESTRICTED INFORMATION" so it can't be reproduced here. However, in my further correspondence I have quoted portions of the Committee Response that clearly did not contain EAR or ITAR material, and I judge that the "NRC Privileged" applied to the Response only while it was in preparation.

I should make it clearer than I did initially that my criticism of the BMD Report and of the proposed system was in regard to its effectiveness in protecting U.S. territory against missile attack from North Korea or Iran. When I briefed the BMD Committee on my

[1] http://www.fas.org/rlg/RLG%20Comments%20on%20Sept%202012%20NAS%20BMD%20Report%20(public).pdf

views on boost-phase intercept May 18, 2010 it was with the hope that they would take into account the means by which a boost-phase interceptor could differ from those for use in midcourse. For instance, the large optics that tends to define a mid-course interceptor kill vehicle would be much smaller for one that sees the bright flame of a missile in boost, and, closer in, needs to distinguish the hard body (by its infrared emission close to or even within the plume). Furthermore, the missile tank for a liquid-fuel missile is far more fragile than is a warhead that is the target of a mid-course intercept. And for a solid-fuel missile, the sturdy rocket body is highly strained under the internal pressure of the burning grain, and even a small hole from a light-weight kill vehicle will cause catastrophic loss of the mission. I disagree with the oft-cited criticism of boost-phase intercept that even if it could be achieved, it might simply result in a warhead directed at the United States falling instead on Canada. We are all in this together, with the United States strongly asserting its right and obligation to protect other NATO members against attack by ballistic missiles, and to protect other allies or friends of the United States. The very thought that four or six successive attempts at mid-course intercept would be advocated by the BMD Committee indicates that the probability of destruction is assumed not to be high. IF boost-phase intercept with a small, fast-burn, high-velocity kill vehicle would have a higher probability of intercept, why would that not be preferable? And boost-phase intercept does not preclude a further effort at mid-course, which has totally different and greater likelihood of being impaired by decoys and other countermeasures.

My two overarching criticisms of the Report of a Committee that had the primary task of evaluating boost-phase intercept was, first, that it summarily dismissed large, fast ground- and sea-based interceptors that admittedly could eventually be defeated by fast-burn solid-fueled ICBMs, but that could have had and could still have a substantial period of effectiveness if they were built and deployed expeditiously. No analysis was given in rejecting this approach, which is one of the two reasons I called the Report "rife with opinion." Incidentally, in my Reply of 11/14/2012, I withdraw this blanket criticism, since I had not yet read the classified document, where I hoped to find more analysis.

When I testified to the BMD Committee May 18, 2010, with my advocacy of boost-phasepl intercept, I hoped that the Committee, in accordance with its name, would perform an analysis of a system optimized for boost phase intercept of North Korean and perhaps Iranian ICBMs, taking into account that for boost-phase, the optics on the kill vehicle could be very different and smaller and lighter than those on the interceptor designed for midcourse. The BPI kill vehicle would need to see from a distance only the intense plume from the rocket engine, and close-up make the divert of some tens of meters from the plume itself to the hard body, for which the BPI KV would need an infrared focal plane, but small in extent and with a small diameter optics in view of the short range. Furthermore, the KV itself against a fragile tank of liquid-fuel missile could be considerably lighter than that to engage a durable warhead. Even for a solid-fuel rocket, the high stress of the booster tank under the pressure of the propellant gases would likely allow a much smaller KV and, accordingly, a proportionately lighter booster train for the interceptor.

The other main criticism was that for the defense of U.S. territory decoys would evidently and admittedly defeat any practical mid-course defense unless, somehow, they could be discriminated and efficiently countered. Neither the unclassified nor the classified Report describes how this could be done, and the unclassified Report states, *"In particular, the committee believes that the best approach for addressing the midcourse discrimination problem is the synergy between X-band radar observations and optical sensors onboard the interceptors with the proper shoot-look-shoot firing doctrine described below."*

Of course, the measure-countermeasure contest is not static, and I have previously given examples of "active discrimination" in which the defense actively perturbs the space objects, and I have indicated how the offense might counter such active discrimination. But active discrimination was evidently not involved in the Committee's assessment. We are left with the statement, *"The committee believes that the key to maximizing the ability to discriminate lethal warheads in the presence of countermeasures is exploiting the concurrent intermittent viewing by X-band radar and interceptor optics for an extended (>100 sec) time as the interceptor closes on the target complex.*

I made a third set of criticisms of the Committee's assessment of the potential performance of the BMD radars.

I should have noted that the Report, as published, did show the system impact of assumed radar performance, extending to cases in which one or more of the radars was disabled. But I judged the Report lacking in the assessment of the capability of individual radars that one might expect from a technical panel.

I am now persuaded by the initiative of one of the authors of the BMD Report that he had indeed provided detailed and competent analysis for the work of the Committee. After the publication of "Making Sense of Missile Defense," Committee Member David K. Barton took it on himself to respond with two highly technical monographs to various criticisms of the Report, especially by George M. Lewis (Cornell) and T.A. Postol (MIT). About these analyses, which he communicated on 11/30/2012 (**X-Band Ballistic Missile Defense Radars, Part I**) and on 01/11/2013 (**X-Band Missile Defense Radars**), Barton wrote that they were based on an assumed cross-section of 0.01 square meters (-20 dB below a square meter, or -20 dBsm). He indicated that the BMD Report itself was based on cross-sections provided by the "government," and those have not been made public.

The BMD Report itself, supported by Barton's extensive analyses, emphasizes that the radar system can do the job only if they are cued in detail by longer-wave surveillance radars, most of them at a great distance, but not so great that they cannot see the "threat cloud" essentially as soon as it is deployed from a long-range missile launched from Iran or North Korea. The threat cloud contains not only the warhead(s) but also fragments of the propulsion tank, hardware, and intentional decoys that might have been released from the missile payload after it achieved ballistic trajectory toward its intended target.

As regards radar I voiced two specific criticisms of the Report:

1. That a paragraph in the Report indicated that for each “target” (including each decoy or fragment) the radar would need to devote a substantial time to exchanging the necessary pulses for discrimination:

> *“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 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.”*

This seemed to me to be quite wrong, not because I challenged the estimate of transit time of the radar pulses, but because provision could be made for receiving the echoes from a compact threat cloud without waiting a separate round-trip transit time for each echo. In Barton’s detailed analysis and in the correspondence he has kindly undertaken with me, he endorses my offer of a summary statement,

> **“The transit time of the radar pulse does not, in itself, limit the number of targets for discrimination.”**

He doesn’t comment on another formulation I offered,

> **"You're right. This is incorrect and misleading. The paragraph (and the criticism) are also irrelevant to the Report, so let's take it as removed from the text."**

My other point concerned the improved “GBX” radar prescribed by the BMD Committee in the form of “two stacked AN/TPY-2 radars,” that double the average power, the radiating area, and the “gain” of the elemental radar that is the basis of the ongoing Phased Adaptive Approach (PAA). (A single AN/TPY-2 radar with netted communications is called by the Committee “FBX”.) This clearly improves the capability of the PAA system, which the BMD Committee judged sorely inadequate.

2. Specifically, my second point was to compare the stacked GBX radar proposed by the Committee with the much larger and earlier GBR (ground-based x-band radar). I pointed out, using the Committee’s own “metric” for discrimination that the power-limited range of the GBX was only 23% that of the GBR. This resulted from a figure of merit (FOM) of the GBX of 1/381 that of the GBR.

I was not advocating the substitution of the GBR for the GBX, but was just curious why the option of a few GBRs doing the job of several times as many GBXs was not considered.

Here I append, identified in green font, my Reply of 11/14/2012 to the BMD's Committee's Response. The Executive Officer of the National Research Council replied 11/15/2012, *"The committee has completed its assignment and was recently thanked by the NRC Chair for serving with distinction and making a significant contribution to the area of missile defense."* so that there would be no forthcoming Committee Response to my Reply. And that further communications should be addressed to the Executive Officer of the NRC. Since I had already addressed to him this 11/14/2012 Reply, and there was no indication then or now of a forthcoming communication, it seemed useless to do it again. I did request that my Reply nevertheless be communicated to the members of the Committee.

I was, then, extremely pleased that, not necessarily in response to my comments, David Barton provided his thorough and public analysis of the radar performance. On the comparison of the GBR with the stacked AN/TPY-2 radar, Barton notes in passing (apparently rejecting the response of the "BMD Committee")

> *"Extended integration times, both for detection and discrimination, are available with all the radars discussed [AN/TPY-2; GBX; GBR-P; SBX], because long-range targets are designated to within a single beam position, and objects from a single missile launch lie within the beam, and the window over which stretch processing is available within the dwell. Only at short ranges might there be a requirement for observation of these objects extending beyond a single beam, and required dwell times at short range are short."*

So the Response of the BMD Committee in explicitly reducing the relative FOM advantage of GBR over GBX from 381 to 19 was incorrect, but that was not part of the Report itself.

That said, Barton indicates that a fundamental reason for choice of GBX over GBR is the ability of GBX to provide electronic scan over an angular range 4.5 times larger than the GBR, and that is an important consideration. Stacking of four AN/TPY-2 would maintain the same electronic scan capability, and so far as I can see is an option not considered in the BMD Committee Report.

Finally, in this comment, I note that the question of warhead cross-section is handled only by reference to "cross-sections provided by the government." The Report also indicates that it would be "difficult" to maintain low cross-section over the broad angular range of view posed by multiple GBX observing the same threat cloud. Long-range rocketry is full of difficulty and that posed by an orientable RV is quite separable.

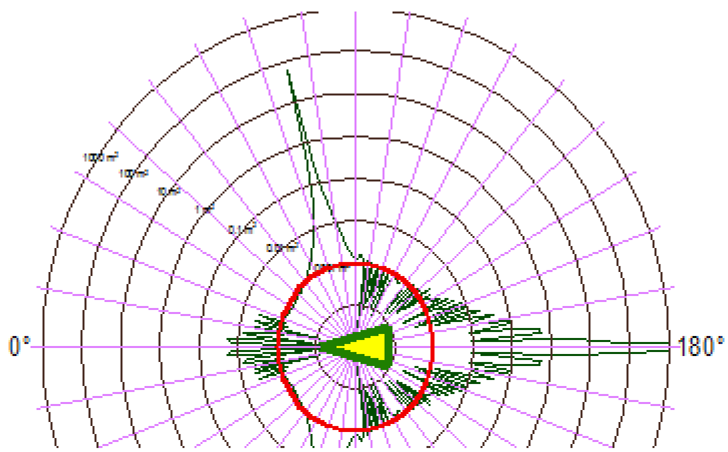
"*Figure 2 below*[2] *shows a polar plot of the radar cross section of a flatback cone that has a thin X-band radar absorbing layer that produces a reflection reduction of roughly 10.*

The cone has a half angle of 15°, a base diameter of 1.5 meters, and a length of 2.9 meters. The 0.001 m² radar cross section values are shown by the red circle. The next

[2] From G.N. Lewis and T.A. Postol material provided to the BMD Committee..

outer circle shows the locus of 0.01 m² values of the radar cross section. As can be seen from the figure, the range of angles over which the radar cross section from the specular reflection off the cone rises above 0.001 m² over an angular range of roughly 30°. The specular reflection rises above 0.01 m² over a range of only 10°. The reflections off the back of the cone are over similar angular ranges."

Of course, a designer hoping to take advantage of these relatively low cross-sections would insist on actual measurements that could conveniently be conducted either in an indoor gymnasium or an outdoor range, taking advantage of short-pulselengths at x-band in order to avoid reflections from nearby objects or structures.



In closing, I thank David Barton for his initiative in communicating detailed analyses of some aspects of radar performance that can be distributed without restriction.

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November 14, 2012
(Via Email to BDarling at nas.edu)

Mr. Bruce Darling
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Dear Bruce and other esteemed colleagues,

On November 1 I received from Ron Taylor the Committee Response to my comments on the BMD report sent to you and others on September 21. It is marked “"NRC PRIVILEGED// INFORMATION DOCUMENT MAY CONTAIN ITAR/EAR RESTRICTED INFORMATION." I asked Ron to send me a copy that is not restricted.

I believe that the Response in some cases does not respond to the criticism, and I propose what I think is a workable means to bring this to a conclusion. The overall questions are the practicality of boost-phase intercept of ICBMs and the effectiveness of the Committee-proposed mid-course intercept system.

The Response contains numbered paragraphs of my original comments and the responses to each numbered paragraph. I focus on my original criticisms of the Report, addressing the Response to the degree necessary to clarify my original point where it did not get across. In a box with heavy border is my original Comment, followed by the Response in a light dotted border.

First, please note:

23. 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.

Committee Response: For all the reasons explained in detail above, we outright reject this shotgun criticism as valid.

Reply to Response: My original comment is unfounded in regard to the scale of analysis, as I have not yet read the classified material in the Report where I may find the radar and discrimination analysis that I seek, so I withdraw this blanket criticism and hope that my apology will be accepted. I go on to the technical issues.

But first I indicate that I will be looking in the classified report for the analysis that is entirely missing in the public report, of such simple matters as how the Committee assessed the performance of radars against nominal RVs of nominal radar cross section, and how it reaches its conclusion that,

> *"an adequate level of discrimination performance can—in the committee's judgment—be achieved in the near term and provide a reasonable chance of keeping the United States generally ahead in the contest between countermeasures and counter- countermeasures over time, at least against emerging missile states like North Korea and Iran."*

I support the Academies' process in the production of these reports, the importance of establishing and maintaining the prestige of the academies in such matters, and I have worked hard for many decades to bring that prestige to where it is now and to maintain it. In addition to serving on many authoring committees and review committees, I worked with NAS President Phil Handler and others long ago to establish the processes that we have now, which have gradually improved, but would still benefit from review and improvement—for instance, by not precluding review of the draft report in an approved facility other than the Keck Center.

I also understand that most of the work is done by volunteer members of the committees and the review panels and that it is a great achievement to have published the Report, and it is a burden to engage in this further discussion.

I can only respond that it is even more of a burden for me, and I don't take it lightly. I have cited often in my public presentations the quote from Einstein engraved in stone on the Keck building, *"The right to search for truth implies also a duty; one must not conceal any part of what one has recognized to be true."* And I trust that in this correspondence we will have no "debating points" substituting for technical discussion. I hope that this correspondence will clarify the technical issues in a collegial manner.

I begin with a particular criticism of a statement that I sensed showed a deep misunderstanding of the radar problem and, if it truly reflected the views of the Committee could lead to significant errors in its conclusions.

The points I raise have no conceivable ITAR/EAR content, so I hope that I may receive a reply quickly so that I can move on to other more specific aspects of the Report and its recommended system. I suggest that the Committee designate for each of these topics an individual on the Committee who will sign the reply, and that the reply be shown to another member of the Committee competent in that field, so that I can be confident that I do have a considered technical reply and am not tilting at shadows.

Because those on the Committee most familiar with fast-burn interceptors are not necessarily those versed in phased-array radars, I propose that the Committee select different volunteers to engage on the different points. I start with a single, well-characterized dispute to ease the burden both on the Committee and on myself--my Item 16-17.

16. 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 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.

Committee Response: One of the virtues of midcourse defense against long range threats is that initial tracking and discrimination are not highly time constrained and the tracking and Doppler imaging revisit time could be significantly greater.

17. 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.

Committee Response: Garwin suggests here that we underestimate the capability of the X-band phased array radars. Much as we would like to believe this, it turns out that his remark is based on older phased arrays using tube transmitters, in which several short pulses could be transmitted into different beam positions, with echoes received by revisiting those positions at the arrival time of expected echoes.

The NRC report is based on full utilization of the average power of the radar, with a duty cycle (the ratio of average to peak transmitter power) of 20%. That means that the transmitted pulse length is 20% of the time between the leading edges of successive transmitted pulses. While there is time available between the end of that transmission and the beginning of reception of the echo from long range, during which receiving beams can be placed anywhere within the scan sector of the array, such operation is not useful. The transmitted pulse contains the maximum energy that is available during the pulse repetition period (limited by heating of the transistor junctions), and there is no advantage to generating extra receiving beams in beam positions where there has been no transmission.

The issue is irrelevant to findings or recommendations in the NRC report and merely suggests that Garwin has knowledge of phased array radars.

REQUEST 1: Can we settle this point, once and for all by agreeing on the statement, **"The transit time of the radar pulse does not, in itself, limit the number of targets for discrimination."?**

Supporting analysis:
If the extent in range of the "threat cloud" is, for example, $дR_{tc}$ = 10 km, a very brief transmit pulse gives rise to a time spread in the return pulse, $дT = 2 (дR_{tc})/c$, with *c* the speed of light, $3x10^5$ km/s. Thus $дT$ = 0.067 ms; a 1-ms transmit pulse illuminating a threat cloud within a single transmit beam would give rise to radar returns in that same beam over a time spread of 1.067 ms, independent of range. If the range from radar to the threat cloud is 2000 km, the echos would be delayed $2x2000/(3x10^5)$ = 13.3 ms, so a pulse train up to 13 ms long would not overlap the return pulse. However, a pulse of duration 1 ms will eventually return as a pulse of 1.067 ms, so a duty cycle of almost 50% could be used without self-jamming of the sensitive receiver elements[3]; tuning the pulse spacing can ensure that the 13-ms delayed pulse does not overlap a transmission interval. The X-band radar used for discrimination is assumed incapable of "search," so that the threat cloud is located by remote long-wave radars.

If the threat cloud spans more than one beam of the discrimination radar, the power output of the radar must be shared among the perhaps several beams, but each of the receive beams need listen for only a short time to the corresponding transmission. For a modern phased-array radar multiple receive beams can listen simultaneously.

In any case, the delay corresponding to 2000 km or 20,000 km does not limit the number of targets (decoys, for instance) that can be assessed.

In addition to Item 16-17, described above, Item 18 is related to individual radars and not to performance of the overall system or to performance against countermeasures, so I include it here:

18. 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

3 In practice a lower duty cycle is used—typically 20%.

with a power output of about 140 kw and a face area of 384 m^2, 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^2 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 $(160*18.4^2)/(140*384^2)$ = 54,170/(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.

Committee Response: The large aperture area of the GBR (and the successor SBX, which is included in the NRC study) causes the solid angle within the GBR beam to be smaller than that of the stacked TPY-2, the ratio being (18.4/381) ≈ 1/20. Hence, the GBR must look sequentially at 20 beam positions to cover objects that are spread over a single beam of the stacked TPY-2. The objects associated with a single missile launch will remain within the stacked TPY-2 beam for a considerable time after the end of boost, during which time the tracking and discrimination data is obtained with a single beam of that radar (but could not with the GBR). Thus the GBR figure or merit is reduced significantly from 381 to 381/20 = 19, corresponding to a range ratio of 2.09, and the stacked TPY-2 radars meet the system requirement when deployed at several locations with overlapping coverage and operated in a mode that takes full advantage of cueing by other elements of the system. Finally, a summary of performance of BMD radars and additional details of the proposed radar architecture are provided in Appendix I and Appendix J, respectively, of the classified annex that accompanies the report.

The Response assumes that the entire threat cloud remains within a single beam of the GBX (the stacked AN/TPY-2), and that there are objects within each of the 20 fine beams of the GBR corresponding to a single GBX beam *at the same range*. At the four-times greater range at which the GBR delivers the same signal-to-noise ratio (S/N) as the GBX against a single target, the threat cloud would fit within a single GBR beam of four-times smaller angular width, confirming my original Comment.

If the GBR were used at the same range as the GBX, it would deliver much better S/N than the GBX against each target—its superiority stemming from the ~20-times larger receiving area (13 dB) even if the energy delivered on each target were no larger for the GBR than for the GBX in the case in which targets are spread uniformly across 20 GBR beams. But if most of the 20 GBR beams are empty of targets or have easily discriminated targets, the GBR has a further advantage up 20 times, or an additional 13dB.

Furthermore, as noted below, the entire face of the GBR can be used for transmitting a beam of the same angular with as that from the GBX, which has a face diameter about four times smaller; one need only provide the phase shifters on transmit with a phase correction corresponding to an outgoing spherical wave of the desired curvature[4].

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[4] I don't know whether the current GBR (the SBX) has this feature.

So what? **The stacked AN/TPY-2 radars proposed by the Committee are far inferior to the GBR for the discrimination role;** whether they are *adequate* depends on the performance of the radar against an assumed nominal (not classified) cross section nowhere stated in the Report and thus unverifiable without critical attention to the classified Appendixes.

ADDITIONAL OBSERVATION:
The Committee-proposed stacking of two AN/TPY-2 radars is an innovative idea that should also be considered for stacking four or more such radars

DETAILED DISCUSSION OF RELATIVE PERFORMANCE OF GBR AND GBX FOR DISCRIMINATION:

We take the GBR to have an active face area of 384 m^2 and an average power of 140 kW. On Receive, the radar has a large number of very fine beams that span its angular aperture. In fact, there are as many beams as there are radiating elements-- ~70,000. On Transmit, one can choose among a number of fine beams corresponding to the Receive beams; radiate with a small quadratic phase shift across the face area to obtain an arbitrarily broad beam mimicking the transmit beam of the GBX; or even, in principle, obtain a pattern of fine beams for transmit—even with different amplitudes in the simultaneous beams.

We discuss here the role of the radar in discrimination, sending a single fine transmit beam sequentially at one of N objects in the target space. Of course, several targets within a transmit beam would be illuminated by a single Transmit pulse and their radar returns (echoes) would be received within a single receive beam, distinguished by their relative ranges enabled by the excellent range resolution enabled by the wide bandwidth of the transmitted pulses.

Roughly speaking, the diameter of the GBR radar face is about 20 m, the wavelength at X-band is about 3 cm, so the angular diameter of a fine beam is about 1/700 radian. At a range of 2000 km, this corresponds to a beam width of 2000/700 = 3 km.

If the GBR were capable of generating only a single fine transmit beam, it could provide one for 1 ms, broken into N (20 or 40) sequential beams during that ms interval; each such sub-pulse would have the full frequency bandwidth of the radar in order to obtain the desired fine range resolution by pulse compression. The radar would then transmit another pulse covering the same N targets 80 ms later for a total of 10 such pulse groups, and repeat those "10-pulse dwells" (the Response suggests four times) over a period of 10 s. This is exactly what is provided in the Response, except that for each dwell, N targets are assessed rather than one.

And if the GBR is capable of providing N simultaneous fine Transmit beams, each with a power 1/N of the total power, the same result can be obtained with 1-ms-duration beams.

If the Committee actually believes the paragraph quoted in italics in my Point 16, it has a great underestimate of the capability of a single high-performance phased-array radar. Perhaps there was an unstated assumption behind this paragraph in the Report that the radar was power-limited at the operating range, but that is a different matter from the asserted fundamental limitation to 16 targets (the reciprocal of 6.4%) at 2000-km range simply because of time-of-flight of radar signals

4. There are some other useful items in my 2005 document[5], particularly p. 13, a configuration for a conical bomblet to deliver BW agents such as anthrax, which, the NAS BMD Report (p. 2-26[6]) states cannot be countered by midcourse or terminal intercept. Even though the NAS authoring committee defined its task as protecting the U.S. homeland against nuclear or other WMD attack[7], this strong conclusion of a free ride for bomblet-delivered BW nowhere figures in its actual Conclusions or Summary.

Committee Response: The Committee understood the submunition threat and addressed solutions. Some of its members had discussed it in the APS report of 2004 that Garwin references in later comments. In the NRC report, we acknowledged the threat from sub-munitions (or other weapons) on missiles launched from ships close to US territory or in theaters of operations as examples of situations where the basing needed for BPI was plausible and suggested that was one of two missions where the barriers to boost phase defense do not exist, pointing out that modifications to existing weapons – not requiring fundamental new development -- could provide that protection in these specialized cases, even though they would not be effective in most cases. These exceptions were highlighted in our briefings to the Hill and DoD, and in the text of the classified annex to the report.*

This Response thus does not forthrightly address Criticism No. 4.
REQUEST 3: Can we agree on the statement, **"Neither the MDA program nor the Committee-proposed system provides any defense against a long-range ballistic missile loaded with multiple bomblets of biological agent, deployed early in ballistic flight."?**

10. 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.

Committee Response: Garwin's opinion reflects a possibility observed in the APS report. Our analysis in chapter 2 with notional 6 km/s interceptors shows that for ICBMs and IRBMs based in central Iran where we believe they would be deployed for protective reasons, a boost

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5 http://www.fas.org/rlg/030605nmdp1.pdf

6 "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."

7 "*(1) protection of the U.S. homeland against nuclear weapons, other weapons of mass destruction (WMD), or conventional ballistic missile attacks"* (p. S-1).

phase defense could be based in southwest Turkmenistan, in southern Azerbaijan or the Caspian Sea. It was the committee's judgment (see p-2-32) that a BPI system dependent on deployment over Central Asian states is unrealistic not only on political grounds but because such a system (whether ground, sea, or air based) would be within range of Iranian hostile action. Such a deployment would not be capable of engaging threats to most of Europe.

Basing in Eastern Turkey is not viable because it could not reach launches from central Iran in time and shorter range missiles based in western Iran burn out at altitudes too low to reach even from eastern Turkey.

Reply to RESPONSE: The Committee Report proposes to deploy a GBX in Azerbaijan for its proposed mid-course BMD; it is not clear why the Committee's political and vulnerability arguments preclude the basing of boost-phase interceptors but permit the basing of BMD radars.

11. 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.

Committee Response: How is this a "major problem" with the report?

Reply to Response:

The Committee states that SLS that includes simultaneous observation of objects in the threat cloud by X-band radar and by interceptor-borne optical and infrared sensors will solve the decoy/antisimulation problem. My judgment on countermeasures (decoys and antisimulation) for ICBMs is not they *cannot* be defeated, but that they *won't* be defeated unless the defense (MDA) accepts that countermeasure technologies available to Iran and North Korea would nullify the deployed system from the first deployments of these offensive missiles. As indicated in several of my publications and in detailed discussion with MDA in the year-2000 time frame, I do believe that "active discrimination" can defeat the decoy/antisimulation threat, although I analyze also countermeasures to that, as an example of the counter-counter-countermeasures contest mentioned by the Committee. In specifying in its report 3-way synergy among X-band radar observation, optical sensor aboard the interceptor, and SLS capability, without any further details in its unclassified Report, the Committee makes a "trust me" case. The absence of any examples of range calculations (S/N vs. R for some arbitrary radar cross section) makes the Report particularly difficult to evaluate.

The Committee asserts that it has a solution to the countermeasures problem by the use of the optical and IR sensors on the interceptors, as if some interceptors are primarily for discrimination rather than destruction. I need to read the classified report, which I plan to do in Washington this Thursday, November 15. After that, of course, I will need to respect the classification of the material, but I will not be inhibited from stating whether or not I am persuaded. And, as usual, I will provide my suggestions to the relevant community as to how the approach might be improved.

PROPOSED FURTHER TOPICS

The siting of radars, the reality of "overlapping coverage," and the system's performance against countermeasures will be the subject of a later communication. And with the use of technical historical data from the Sprint BMD interceptor missile from the 1970s and other tested technology I will review the Report's dismissal of the practicality of 10 km/s high-acceleration interceptors based on land or sea for boost-phase intercept of ICBMs from North Korea or Iran.

Thank you very much.

Sincerely yours,

/ Dick Garwin /

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