Response to Uzi Rubin's "Comments on the UCS Report on Countermeasures"
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We recently received—via a third party—a critique of our report, ***Countermeasures***.[2] The critique, written by Uzi Rubin and titled "Comments on the UCS Report on Countermeasures," is dated 18 July 2000. Rubin states that his study was "considerably less exhaustive" than the countermeasures report and was done by "a small team of experienced missile engineers." Rubin's critique has not been published, but instead has been distributed informally in the United States.

Here we respond to Rubin's points in the order that he makes them. As we will make clear, Rubin's criticisms are either technically invalid or based on incorrect characterizations of the assumptions that underlay our work.

Rubin states that "The [UCS/MIT] report is well researched, and its arguments are based on very detailed calculations. …We have checked some of the key calculated results presented in the report, and found them entirely correct if somewhat conservative. We therefore assume that the authors did a very thorough job, and all the calculated results presented in the paper are impeccable." This makes clear that Rubin's critique is not based on our technical analysis.

Key assumptions:

Rubin argues that our analysis is "based on assumptions that are biased in favor of the threat and against the defense, and that without such biasing, the conclusions could be significantly different." He makes four comments on our assumptions, having to do with (1) the technical capability of an attacker; (2) the difficulty of implementing the countermeasures discussed in our report; (3) the ability of the NMD system to change in response to countermeasures; and (4) the required level of effectiveness for the NMD system. We next show that each of these criticisms is incorrect.

(1) Technical capability of an attacker

Rubin states:

> "One key assumption in the report is that anybody who can make nuclear tipped long range missiles could easily design, test and deploy the countermeasures described in the report. This assumption puts no upper limit on the aggressor's technological prowess.

[1] The other authors of the UCS/MIT Countermeasures Report (see next footnote) have not seen this draft, and are therefore not listed here.

[2] Andrew M. Sessler (chair of the Study Group), John M.Cornwall, Bob Dietz, Steve Fetter, Sherman Frankel, Richard L. Garwin, Kurt Gottfried, Lisbeth Gronlund, George N. Lewis, Theodore A. Postol, and David C. Wright, *Countermeasures:A Technical Evaluation of the Operational Effectiveness of the Planned US National Defense System*, April 2000 (Union of Concerned Scientists and MIT Security Studies Program, Cambridge MA). Available at www.ucsusa.org/arms.

> While admitting that it is difficult to draw a line between 'simple' and 'sophisticated' countermeasures, we believe that the lack of an upper technological boundary on the aggressor put[s] him in the league of a superpower as far as countermeasures are concerned. Thus, the report is pitting the NMD not just against missiles that could be made by an emerging rogue state, but against the best that could be thrown at it in the distant future by an advanced country."

In fact, we do not assume limitless technological prowess on the part of the attacker. Indeed, we discuss three countermeasures in detail to make clear what technologies and level of sophistication would be required to implement them. We assume that the attacker can make a long-range missile and a nuclear or biological weapon to arm it with, and therefore possesses the technology and the scientific and engineering expertise required to do so. This is appropriate because that is the stated rationale for the US NMD.

Specifically, we assume a potential attacker can build: a multi-stage intercontinental-range missile with a payload of 1,000 kilograms; guidance accurate enough to target a large city; either a biological weapon containing anthrax or a nuclear warhead compact and light enough to be carried on the missile; and a reentry vehicle capable of shielding the warhead from reentry heating. We also assume that the conclusions of the unclassified summary of the September 1999 National Intelligence Estimate are correct: that an emerging missile state could use "readily available technology—including separating RVs [reentry vehicles], 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… by the time they flight test their missiles."[3]

This does not put the attacker "in the league of a superpower," nor make its countermeasures "the best that could be thrown at it in the distant future by an advanced country," as Rubin asserts. We did not discuss potential countermeasures that we considered likely to be beyond the technical capability of an emerging missile state. Rubin's claim that we assume no upper bound on the technology used by the attacker is incorrect and unfounded.

(2) <u>The difficulty of implementing the countermeasures in our report</u>
Rubin states:

> "The second key assumption is that the described countermeasures are characterized as 'simple'. … We believe that all the countermeasures described are far from 'simple'. While they are easy to conceptualize, they are not easy to implement." He also states the the UCS/MIT Countermeasures Report "describes at great length how the proposed countermeasures will degrade the NMD, but is silent on the formidable engineering challenges of designing, testing and integrating them into rudimentary ballistic missiles of rogue states."

This criticism is closely related to the first one. The relevant question is not whether a countermeasure is simple on an absolute scale, but whether it is simple to implement *relative* to building an ICBM with a nuclear or biological warhead, which any attacker would be able to do.

[3] National Intelligence Council, "National Intelligence Estimate (NIE): Foreign Missile Development and the Ballistic Missile Threat to the United States Through 2015," unclassified summary, September 1999.

A potential attacker would have substantial missile and warhead design teams with considerable experience in a range of relevant technologies. As noted above, we assumed a level of engineering capability that any country capable of building a long-range missile would have to possess. We also assumed that countries would be able to implement the technologies mentioned in the September 1999 NIE. In fact, many of the materials and technologies we discuss were developed decades ago.

By analyzing three specific countermeasures, we were able to consider the various steps required to implement them. We do not believe that any of these three would present significant difficulties to a country capable of building long-range missiles.

Moreover, an attacker would have adequate time to develop countermeasures to the defense since it will have many years of warning that its long-range missiles would face a missile defense. It has been clear since 1996 both that the United States was moving towards NMD deployment and what the nature of the NMD system would be. The first stage of the NMD system being developed and tested now will not be deployed for another 5 to 6 years.

(3) <u>The ability of the NMD system to change in response to countermeasures</u>
Rubin states:

> "The report and its conclusions are based on another, albeit hidden assumption: That the NMD configuration is frozen in its current design features. Thus, while the authors of the report allow the missile designers of low tech countries a free hand in inventing an increasingly clever series of countermeasures, they exclude the prospects of the inevitable response of the NMD designers by introducing improved and enhanced versions of the NMD building blocks. No major weapon system is ever static; it grows and evolves from its initial baseline configuration in response to the growth of the threats. It stands to reason that the US designers will react to the introduction of challenging countermeasures, once the evidence of their existence is verified through intelligence sources or by observing the adversary's flight tests, and that the NMD would be enhanced and improved accordingly."

Our analysis assumes that the basic NMD configuration is fairly well-set, because the United States is close enough to a deployment decision that it has to be. Thus, the system will use hit-to-kill interceptors, early-warning and X-band radars, and space-based infrared and visible sensors. However, the report takes as its baseline the *full* NMD system that is planned—which will not be deployed until at least 2010. This is the system that the Pentagon claims will be capable of dealing with "complex" countermeasures. We show that this claim is incorrect.

Our assumptions in this regard are neither hidden nor biased. We explicitly state that we consider the full proposed NMD system, without major modification. It makes perfect sense to analyze the system that the United States is planning to deploy.

We did consider several modifications to the NMD system that did not require major hardware changes but might serve as counter-countermeasures. To counter the cooled shroud countermeasure, we considered the possibility that the kill vehicle could use the existing visible

sensor on the kill vehicle for homing (it is currently not configured for homing). As we discuss on pages 87-89, we found that the attacker could also deny homing by visible sensors.
For anti-simulation balloons, we considered the possibility of waiting to divert interceptors until the balloons were low enough in altitude that atmospheric drag could be used to discriminate the empty balloons from the ones containing warheads. However, we found that even this "last-ditch" strategy would not permit the NMD to counter anti-simulation balloon decoys.

There are no modifications that would allow the planned NMD to counter submunitions, because doing so would require an entirely different approach, such as a boost-phase system.

Rubin assumes that US designers will know in advance what countermeasures an attacker has developed, "through intelligence sources or by observing the adversary's flight tests," and will know this sufficiently in advance that the NMD could be modified accordingly. We believe this assumption is overly optimistic.

The United States is likely to know very little about the countermeasures a potential attacker might deploy. An attacker will understand the importance of not divulging such information. As the Rumsfeld Commission emphasized, emerging missile states are increasingly able to conceal sensitive activities. The countermeasures we described could be deployed with considerable confidence without flight testing, after sufficient testing using ground facilities and, where appropriate, airplanes.

The offense has important advantages over the defense in this regard. Because the United States is a relatively open society, and the NMD system must go through a multi-year test program in advance of its deployment, the attacker will know a great deal about what sensors and components the NMD system will incorporate. The attacker will have this information well in advance of US deployment, and can tailor its countermeasures to the specific NMD system.

In contrast, the United States may know little about the countermeasures an emerging missile state is developing. And even if the United States made major hardware changes to the planned NMD system to counter some of the countermeasures we discuss, it would take years to develop, test and deploy the new hardware, giving the attacker both the information and time needed to take additional steps to defeat it.

(4) <u>Required level of effectiveness for the NMD system</u>

Rubin states:

> "Finally, the report takes it for granted that the NMD's mission is to prevent the impact of any kind of payload delivered by a rogue country missile on the territory of the US. Upon reflection, this criterion for the NMD's measure of effectiveness could be judged as overly severe. A more reasonable measure would be the prevention of unacceptable damage from a rogue country missile, 'unacceptable damage' being defined as a significant effect of mass destruction."

According to the US government, the purpose of the planned NMD system is to defend against long-range missiles armed with "weapons of mass destruction," and this is the criteria we use in our report as well. It is simply not true that we assume that the purpose of the NMD system is to prevent the impact of any kind of payload on the United States. Although the US government apparently considers chemical weapons to be a “weapon of mass destruction,” we note in our report (chapter 2) that only nuclear weapons and some biological weapons deserve the title “weapons of mass destruction.”

Next we show that the criticisms made by Rubin of the specific countermeasures we discuss are incorrect.

Submunitions:

First, we note that Rubin confirms that: “The submunitions described in the report – spheres and spherical tipped cones – are viable. They are well protected against the thermal stresses of reentry, and will reach the ground in one piece, albeit at relatively low speeds due to their very low ballistic coefficients which will slow them down to terminal velocities at a very high altitude.” Despite the clear evidence that such submunitions are feasible, this issue is still in contention in US policy circles.

However, Rubin’s assertions about the lethality of agents deployed in submunitions are not supported by the facts. He states “Without doing any detailed calculation, we suspect that a concentration of one 2.2 Kg. load [of agent] per 4 square Km. will cause, at most, some local damage; it is hard to see it creating anything akin of ‘mass destruction’.”

As we discuss in Chapter 2 of the Countermeasures Report, while chemical weapons and many biological weapons may not deserve the title “weapons of mass destruction,” anthrax spores and certain other *infectious* organisms certainly do.

For example, based on calculations performed by Dean Wilkening at Stanford University using a computer code distributed by the Defense Threat Reduction Agency,[4] we find that 100 bomblets each distributing 2 kg of anthrax slurry per 4 square kilometers could kill over 100,000 people if the distribution efficiency is 1% and the average population density is 3,000 per square kilometer (typical of US cities).

Rubin’s assertion that a submunition attack is an “almost insignificant threat” is clearly wrong. In fact, the number of deaths caused by one missile carrying 100 anthrax-filled submunitions would be comparable to (and could be greater than) the number caused by the 15 kiloton bomb the United States used on Hiroshima, which resulted in roughly 100,000 deaths.

Because the effects of any biological attack would depend on many factors—including the weather—it is difficult to make general predictions about such attacks, whether delivered by submunitions or unitary warheads. However, an important variable is the fraction of the agent that is released in the form of particles small enough to be inhaled but large enough to be retained in the lung. Submunitions may provide an advantage to the attacker since it may be

[4] Dean Wilkening made the following assumptions in his calculations: the bomblets were distributed over a circular area with a radius of 20 kilometers; LCt50 = 0.1 mg-min/m3 and probit slope of 0.7 (corresponds to LD50 = 20,000 spores if we assume breathing rate of 0.007 m3/min (resting) and a slurry concentration of 30 million spores per mg; if breathing rate were three times higher (light activity) and slurry concentration two times higher, LD50 = 3500 spores.); typical weather (randomly selected for Washington, DC).

easier to disperse a higher fraction of the agent in the ideal size particles using submunitions because at low altitudes they would travel at slower speeds than a large unitary warhead. We note in the report (pg. 57) that the low speeds of the bomblets as they near the ground are comparable to aircraft speeds and might make it possible to use a small sprayer to release the agent. Since sprayers can release the agent in the optimal droplet sizes, using sprayers could be a very efficient way of releasing the agent. Thus, the relevant comparison may be between a 600-800 kilogram unitary warhead that releases a small fraction of the anthrax as a respirable agent, and 100 two-kilogram bomblets, each of which release a larger fraction of the anthrax as a respirable agent.

Submunitions likely have another advantage over unitary warheads. The lethality of a biological attack depends not only on the potentially lethal area of dispersed agent, but also on the population density within that area. A unitary warhead deposits its agent in a small area, and the agent is then carried by the wind into a long, thin plume, much of which may lie outside of the metropolitan area. Submunitions instead create many smaller plumes that can be spread out to more effectively cover a populated area.

We agree that "effective passive defenses" against chemical and biological agents are "readily available." For example, if buildings were routinely built so that they contained filtered air at a small positive pressure relative to the outside, such passive defenses could reduce the effectiveness of an attack by a respirable biological or chemical agent by a factor of ten or more for those in such buildings during the cloud passage. However, the United States does not plan to employ such passive defenses on a widespread basis, despite the fact that some of us have urged for years that buildings, beginning with US government facilities, install positive pressure filtered air systems.

It is also incorrect to assert, as Rubin does, that the NMD would compel an attacker with a nuclear weapon to substitute biological or chemical weapons. An attacker with a nuclear weapon could use another countermeasure appropriate to nuclear weapons, such as cooled shrouds and anti-simulation balloon decoys.

Finally, Rubin claims that it would be difficult for an attacker to disperse the submunitions. He states that if the attacker "chooses a controlled post boost phased dispersion, as described in the report, he must include a closed loop attitude control system in the warhead section of the missile… " and that these would "complicate the aggressor's missile design beyond what could be described as rudimentary."

First, we note that the first and simplest dispersal method discussed in our report (p. 55) requires nothing beyond the standard control system needed for the missile itself. The dispenser would remain attached to the final stage at burnout and would use springs to kick out the bomblets in a range of directions with a range of speeds. No maneuvering or control beyond that needed to get the missile on the proper trajectory in the first place, would be required.

With respect to the second dispersal method the report discusses, the 1999 National Intelligence Estimate makes it clear that the technology required for attitude control will be available to emerging missile states. Specifically, the NIE notes that an emerging missile state would be able to use “RV reorientation.” The attacker would be able to use exactly the same technology to reorient the bomblet dispenser after boost phase.

Cooled Reentry Vehicles:

Rubin has two basic criticisms of the cooled shroud countermeasure: that it would be difficult to implement and easy to defeat.

He argues that there are two reasons it would be difficult to implement. First, “While this concept is elegant, we suspect that it is harder to translate it into real hardware than what the report leads the readers to believe. The hollow, thin walled shroud must withstand the shocks, vibrations and aerodynamic loads throughout the boost phase without buckling. It must be designed as a flight critical item, with the required structural strength, thermal shields and their associated margins of safety. The insulated reservoir must be integrated with the reentry vehicle and carry the associated logic and squibbing devices.”

This is true, but does not imply technical barriers. The attacker is assumed to be able to build a long-range missile, which means that it has successfully designed a number of flight-critical items and integrated them into the missile. The attacker would have a demonstrated ability to design and build structures capable of withstanding the stresses involved in a ballistic missile launch. Information about the properties of various materials is readily available in common reference books.

According to Rubin, the second difficulty in implementation is that the reservoir of liquid nitrogen must be topped off shortly prior to the missile launch. He notes that “For liquid propellant missiles that are fueled before flight, this is not a significant hurdle. For storable or solid propellant type missiles, the topping adds some complication. In addition, the limited shelf life of the cryogenic fluid will place an upper limit on the duration of the missile’s readiness status.” This argument is not compelling for several reasons. The main focus of the US NMD program is emerging missile states such as North Korea, which are developing liquid-fueled missiles. In this case, as Rubin notes, topping off the reservoir would not be an issue. Moreover, these states are not expected to keep their missiles constantly prepared for quick launch, and would ready them for launch shortly before they intended to use them.

Rubin also states that the cooled shroud countermeasure is “relatively easy to defeat” and suggests that “a future version of the EKV could be equipped with a short range radar sensor, based on the Arrow or the PAC – 3 onboard radar sensor designs.” “As tabulated in page 85 of the UCS report, a radar sensor with an acquisition range of no more than 10 Km will permit a relatively mild, 4g maneuvering authority to achieve a successful endgame. Such an upgrade should not be prohibitive, and we see no reason why it could not be implemented in an NMD future configuration, if there is evidence that cooled reentry vehicles are a realistic threat.”

However, it is not clear that an onboard radar sensor based on the Arrow or PAC-3 designs would be feasible in this case, because the closing velocities would be greater and the radar cross section of a shaped shroud would be far less than that of a theater missile with no separable reentry vehicle. Even if a radar sensor was feasible, adding it to the kill vehicle would require a significant design and testing program, giving an attacker advance warning of its existence. The attacker could respond, for example, by adding radar corner reflectors on very thin booms, which would give very large radar returns and serve as decoys for the homing radar.[5]

Anti-simulation

Rubin begins his comments on nuclear weapons with anti-simulation balloon decoys by stating: "The third and most formidable countermeasure strategy described in the report is 'antisimulation'. …The idea of antisimulation is so elegant, in fact, that we wonder why it is not already a standard countermeasure feature of the US and UK strategic forces. The lack of literature on antisimulative countermeasures could either mean that their very existence is a highly guarded secret, or that they are impractical and therefore not in use. For the sake of the present comments, we shall assume the latter…"

First, we are surprised that Rubin thinks there is no literature on anti-simulation. It was introduced in the US strategic discussion in the mid-1960s. It is described in considerable detail in the papers by Bethe and Garwin,[6] and was even featured in the title of a 1987 article by Edward Teller: "Minuteman Needs Antisimulation Decoys."[7]

On the other hand, the US military has apparently considered anti-simulation to be a sensitive topic. For example, Pentagon reviewers required that the term "anti-simulation" be removed from the final version of the American Physical Society's July 1987 report on Directed Energy Weapons.

But there is no mystery why the US and UK strategic forces have not employed anti-simulation countermeasures of the type we discuss. The anti-simulation countermeasure described in our report would work against a hit-to-kill exo-atmospheric interceptor. US and UK countermeasures were designed to defeat a Russian missile defense that protected a relatively small area, was armed with large-yield nuclear warheads, used both exo- and endo-atmospheric interceptors, and used only a radar for tracking and discrimination. The fact that no optical or infrared sensors were used means that full anti-simulation was not needed for viable decoys. The Moscow engagement radar, which operates at a low frequency of about 450 MHz, would have a relatively large wavelength and poor resolution. Thus, even simple chaff would be very effective as a decoy. The United States apparently planned to use chaff as well as precursor nuclear explosions to destroy the single radar.

Moreover, the fact that the Russian defense uses nuclear-tipped—not hit-to-kill—interceptors means that one interceptor could have destroyed multiple balloons, and would have made such

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[5] Radar corner reflectors are simply three pieces of highly reflective material attached to each other to form a corner (i.e., it would look like an inside corner of a box). The shape is such that any radar waves that reach the corner reflector would be reflected back in the direction they came from, resulting in a very large radar return (or radar cross section). As we note in Appendix C (p. 132) a trihedral corner reflector has a maximum cross section of $12\pi a^4/\lambda^2$, where a is the length of each side and λ is the wavelength of the radar. Thus, a corner reflector with sides of length 10 centimeters would have a RCS as high as 4 square meters for an X-band radar, and 40 square meters for a K_a band radar of the type used on Arrow.

[6] See, for example, Richard L. Garwin and Hans A. Bethe, "Anti-Ballistic-Missile Systems," *Scientific American*, March 1968, pp. 164-174; Richard L. Garwin, "The Soviet Response: New Missiles and Countermeasures," in *Empty Promise*, John Tirman, ed. (Boston: Beacon Press, 1986), pp. 129-146.

[7] Edward Teller, "Midgetman Needs Anti-Simulation Decoys," *Armed Forces Journal International*, March 1987, p.44.

decoys less effective. Finally, since lightweight anti-simulation decoys are only effective outside the atmosphere, Russia's inclusion of endo-atmospheric interceptors would have also have made anti-simulation balloons ineffective.

Rubin also argues that it may be too difficult for an attacker to build an effective decoy balloon. He cites three potential difficulties: (1) constructing the balloon around the warhead; (2) protecting the balloon during boost phase and release; and (3) attaching the balloon to the warhead. We will discuss each of these issues in turn, showing that none of these are difficult.

<u>Putting the warhead inside the balloon:</u>
Rubin first argues that it may be too difficult for an attacker to build an effective decoy balloon around the warhead. He correctly notes that the warhead must be attached to the missile body by metal-to-metal fittings, that the warhead and missile will need to be connected via cables, and that service hatches must remain accessible during flight preparations. However, he claims that this means that the balloon surrounding the warhead "cannot have a continuous structure, and must consist of segments, each firmly cemented to some part of the reentry vehicle along leak proof joint lines, or of several separate cells. In any case, the balloon will not resemble the simple, smooth spherical balloons depicted in the report."

This is not true. There are ways an attacker could put the warhead inside one balloon while allowing supports as well as cables and wires to pass through the balloon from the final stage to the warhead. We describe one way below in detail (and we have previously provided the US Department of Defense with this description as well).

First note, though, that the balloons need not be spherical. In the report, we discussed spherical balloons for three reasons: (1) it is an easy way to make a decoy, (2) a lot of information is available about the spherical NASA Air Density Explorer balloons, first launched in 1961, and (3) calculations of the equilibrium temperature of the balloons with and without a warhead are simpler. As we note in the report, however, there could be advantages to making the balloons all slightly different shapes, so that there would be a variation in equilibrium temperature due to shape during nighttime trajectories.

The RV might be mounted onto the third stage of the missile in several ways. Here, we will consider RVs that are "post mounted," although they could instead be mounted with a ring clamp around a metal base.

During launch, a post-mounted RV might be attached to the final stage by three posts projecting from its lower (back) end. As we describe in the report, the attacker could make each balloon from several pieces of aluminized mylar. To allow the mounting posts to penetrate the balloon, the attacker would cut holes for the posts. The attacker could then reinforce each hole with a rigid plastic grommet to prevent it from tearing and attach a plastic flap on what will be the inside of the balloon (one over each hole) using, for example, double-sided tape. The plastic flap would be "springy" so that it would spring back to seal the hole once the mounting post (or whatever was passing through the hole) was removed. Once inflated, the gas pressure will also help the flap to stay closed. (This is the type of flap that is used in air mattresses.) But the flap does not need to close tightly since a slow leak is fine (as we note in the report, the balloons could be designed to allow the inflating gas to leak slowly out of the balloon.)

The attacker could then slip the part of the balloon with the holes in it (with its flaps open) over the three posts at the top of the third stage of the rocket and attach the RV to the posts. The attacker could then finish making the balloon around the RV, as we describe in the report.

As we discuss in the report, the balloon could be attached to the RV using strings of the proper length so that when the balloon is inflated, the strings would be taut. (Rather than attaching the strings directly to the RV, it might be preferable to attach them to a string "cradle" which itself was attached tightly to the RV.) Once inflated, there would be dimples on the balloon surface where the strings are attached.

We assume that the RV would separate from the posts just at the back cover of the RV. A half-turn of the posts might disengage them from the RV base, and a spring (or 3) might separate the RV from the third stage until a small rocket diverts the third stage away from the warhead (and decoys). Any electrical connections to the RV could be snaked down next to a post and would then be severed when the RV separates.

The attacker would want to construct each of the decoys in a similar but not identical way--by cutting three or more holes in each balloon and attaching a grommet and flap over each hole. In this case, the balloon could be assembled around the inflating mechanism. Each of the decoy balloons should have a similar string configuration on its inside, attached to a string cradle that has no RV within it. Thus, the decoy balloons will have the similar dimples, grommets, and flaps as the anti-simulation balloon enclosing the RV. But by making all the balloons slightly different (using signature diversity), it would be even more difficult for the defense to discriminate the balloon with the warhead from the decoys.

Each of these decoys could be placed in a canister and ejected after boost phase, or the inflating mechanism inside each decoy could be mounted directly to the third stage using a small post inserted through one of the holes in the balloons.

As discussed in the Report, after the RV separates from the final stage and the decoys are ejected, the balloons could be inflated using either a small gas bottle, as was used for the NASA Air Density Explorer balloons, or a small gas generator. Also, as we note in the report, the attacker would not need to "spin up" or reorient an inaccurate RV.

When a decoy balloon inflates, whatever minor spin rate the decoy has will be greatly reduced by the large increase in its moment of inertia. The attacker would probably want to arrange the string cradles so the center of mass of the RV is near the center of the antisimulation balloon, and the inflation hardware for the decoys is near the center of the decoy balloons.

Any service hatches can be made accessible through a flap that could be taped closed before launch. Of course, the decoys would be made with similar hatches, taped closed.

<u>Protect the balloon during boost phase and release:</u>
Rubin correctly notes that the balloon surrounding the warhead would need to be protected by a shroud during boost phase. However, his statement that such a shroud “is a major technical

challenge by itself" is incorrect. North Korea successfully used a shroud on its August 1998 flight of the Taepo-Dong 1 missile, in which it attempted to launch a satellite.

Rubin is correct that the balloons would need to be protected during the release of the shroud. However, he is incorrect in stating that this would preclude using simple pyrotechnic devices to release the shroud. Pyrotechnic devices do not inevitably result in debris; many such devices are fully contained.

<u>Attaching the balloon to the warhead:</u>

Rubin states that it would also be difficult for the attacker to attach the balloon to the warhead to prevent the warhead from tumbling about and tearing the balloon. He states "This would probably require some internal trussing between the balloon's skin and the reentry vehicle structure, perhaps in a form of an array of stiff spokes which could deploy, umbrella like, upon the balloon's inflation. This, in turn, would require anchor points in the reentry vehicle and in the balloon's skin." However, as we note in the report (pg. 69) and discuss above, the attacker could attach the balloon to the warhead using strings that would be slack when the balloon is uninflated and under tension when the balloon is inflated. The decoy balloons would have a similar internal string structure. Of course, the attacker would want to reinforce the balloons where the strings were attached to it, but this would be required for all the balloons. None of this would be difficult for a country that could build a long-range ballistic missile.

<u>Defeating anti-simulation balloons</u>

Rubin acknowledges that if an attacker deployed anti-simulation balloon decoys, this would pose a serious discrimination challenge to the NMD. He then states that discrimination might be possible if the defense could observe the boost phase of the attacking missile and measure with great precision the velocity of the missile at the "moment of thrust termination." He notes that the radars and other sensors (including SBIRS-low) that would be deployed as part of the planned NMD system would be inadequate to do so, but that future systems could perhaps include additional X-band radars that would be either ship-based or forward deployed close to the launch site, and "space systems with improved detectors." Of course, this would not be a minor adjustment to the planned NMD system. But, more importantly, there are—even in principle—two problems with this method of discrimination.

First, because radars can only accurately measure an object's velocity along its line-of-sight (in the radial direction to the radar), the defense would need multiple radars close enough to observe the boost phase in order to determine the total velocity at thrust termination. Second, and more important, even if the defense could determine the *exact* velocity of the final stage plus payload just prior to burnout, this would only provide information about the trajectory of the center of mass of the final stage and payload. Rubin seems to assume that the warhead would be so heavy relative to the other objects released that it would essentially be at the center of mass. But he has ignored the final stage itself, which will also contribute to the motion of the center of mass. Since the final stage will have a significant mass, and the defense will not know what the exact mass of the final stage is, it will not be possible for the defense to predict the trajectory of the warhead with enough precision to distinguish the balloon with the warhead from the empty balloons.

Rubin also mentions the differential effects of atmospheric drag on the lightweight balloons and the balloons containing warheads. In our report, we discuss in great detail the potential of using this effect to discriminate in early reentry (pages 70-79), and find it not to be feasible for a defense that uses exo-atmospheric interceptors, as does the planned NMD system. Nor would it be possible to use this effect to discriminate immediately after boost phase, since the attacker could simply wait for the missile to get a bit higher before releasing the balloons.

Rubin then raises another problem for the NMD system that our report does not even consider: the possibility that the balloon surrounding the warhead could foil the hit-to-kill intercept. Rubin notes that the warhead would only occupy a fraction of the balloon's volume, and states that the kill vehicle could pass through the balloon without hitting the warhead. The balloons we discuss in our report are small enough that if the kill vehicle hits the center of the balloon, it would very likely destroy the warhead. However, it would be possible to use larger balloons. We briefly discuss the idea of using much larger balloons to lower the kill probability on page 48 of the report; such larger balloons could be used individually or in combination with smaller balloons.

However, Rubin's solution to this potential problem (which is only worth solving if the discrimination problem can also be solved) is that future kill vehicles "be equipped with small lethality enhancers containing enough fragments to ensure warhead kill." But the Pentagon presumably believes that doing so would reduce the capability of the NMD system, or else it would not have chosen to use a kill vehicle that relied on hit-to-kill technology.

Concluding Remarks

Rubin's final criticism concerns our statement that Russia and China would respond to a US NMD deployment in ways that would decrease US security. Rubin states, "We find this particular argument, made against the backdrop of a very exhaustive study striving to prove that NMD is practically useless, as very perplexing. If the authors believe their own case, Russia and China should have no reason for alarm – simply reading through the UCS report would quell their concerns over NMD, and the only race would be to produce the allegedly simple countermeasures described in it. Alternatively, if the authors do indeed believe that an arms race could be unleashed as a response to what they describe as a very ineffective defense system, it might indicate that they doubt the conclusions of their own study. The report does not offer any clarification to this puzzling contradiction."

Ironically, the answer to this dilemma is Rubin's own critique of our report. If Rubin were advising Chinese or Russian policy-makers, he would be telling them that the US NMD could defeat these countermeasures, which he regards as quite sophisticated.

Our report discusses this issue at length in Chapter 12. We do not suggest that China and Russia would find it difficult to implement countermeasures that would defeat the planned US NMD system. However, we believe that bureaucratic and military pressures in China and Russia would lead these countries to not only implement countermeasures, but also to modify their offensive nuclear policies. They might choose to increase their arsenal or refuse deeper cuts, retain or deploy multiple warheads on missiles, and rely more heavily on a launch-on-warning strategy.

As scientists who have served as consultants to the US military can testify, although Russian and Chinese scientists will understand that the US NMD system would be vulnerable to countermeasures, their political and military leaders are instead likely to doubt that the United States would pour billions of dollars into an ineffective system. A US NMD system would create uncertainties against which Russian and Chinese military planners would want to hedge. This is particularly clear in China's case: China currently deploys some two dozen single-warhead missiles capable of reaching the United States, which is the scale of the attack that the NMD system in intended to defend against.

In addition, Russian and Chinese leaders will realize that US actions will be based not on the system's actual effectiveness, but on US perceptions of its effectiveness. China, especially, may feel that it needs to take visible steps such as increasing its missile arsenal to make unambiguous its ability to penetrate the US NMD.