The United States Should Develop a Missile Defense System That Builds Confidence

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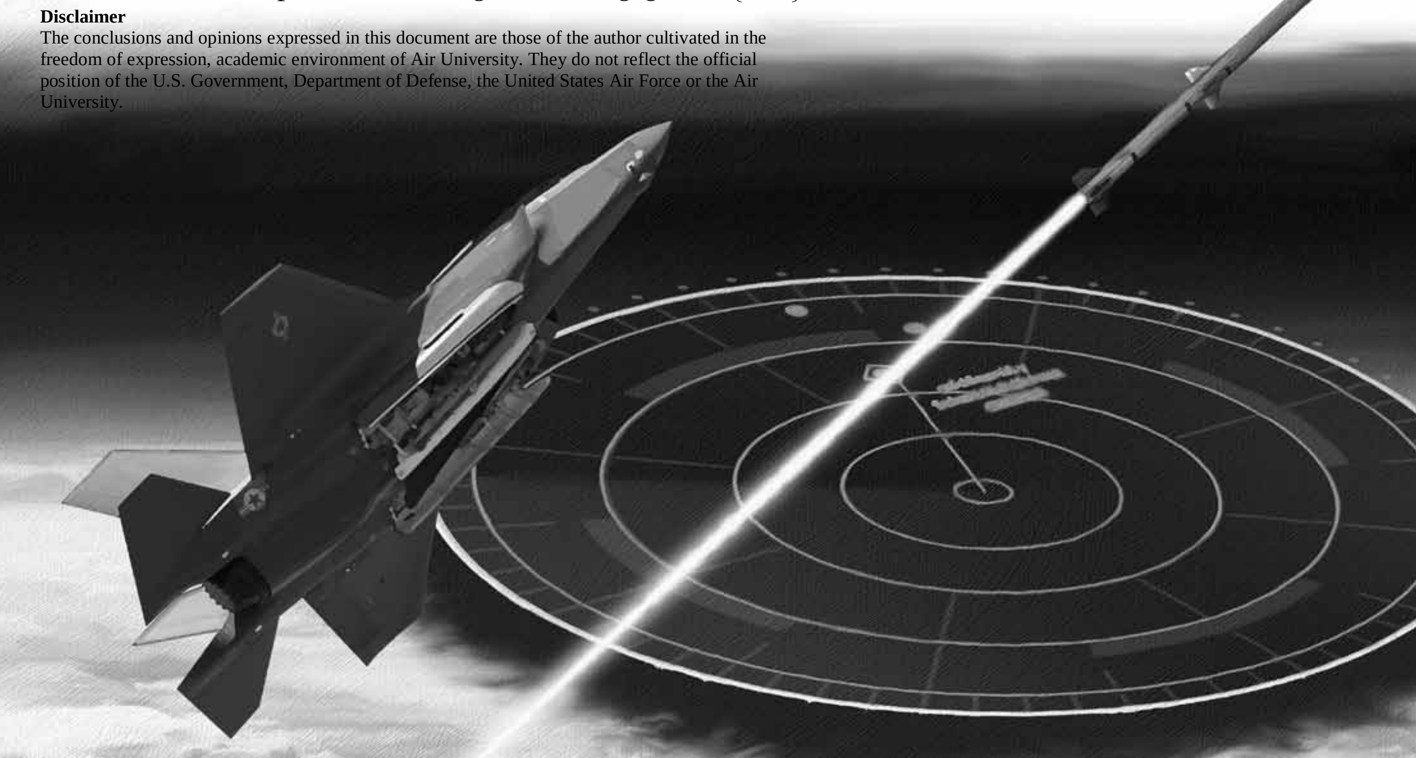
System performance is an essential factor in determining military utility; it is even more critical with respect to deterrent effects. Test failures, unless refuted by a string of successful tests, can erode our confidence and the system's value for deterring our adversaries. In addition to component failures, defensive systems must also cope with unknown target characteristics and maneuvers that can yield missed intercepts even when all systems are functional. Realistic operational testing defines engagement envelopes where we expect success if everything works, but it takes *many* tests.

The ground-based midcourse defense (GMD) missile defense system has not performed to expectations in recent tests, and some individuals even question the feasibility of midcourse intercepts themselves under realistic combat conditions. However, GMD's greatest challenge may not be identifying and correcting the causes of recent test failures but testing enough to regain military confidence and define its operational envelope.

This article examines an alternative concept and the defensive capabilities we could gain by equipping air sovereignty alert (ASA) forces with missile defense sensors



and small, air-launched interceptors currently under evaluation by the Missile Defense Agency (MDA) and the Air Force as the Airborne Weapons Layer. It depicts this concept's predicted capabilities under two scenarios: (1) a short-range ballistic missile launched from a ship offshore, and (2) an intercontinental ballistic missile (ICBM) launched from Iran without warning. Finally, the article discusses an operational testing concept focused on building confidence in the proposed defensive system.

Criticisms of Our Missile Defense System

The November/December 2010 issue of the *Bulletin of the Atomic Scientists* includes an article entitled "How US Strategic Antimissile Defense Could Be Made to Work" by two leading critics of the US missile defense system.[1] Authors George Lewis and Ted Postol have a long history of criticizing that system, and many people close to the program consider them opposed to the missile defense mission in general. However, in this article they do not declare missile defense unnecessary or impossible but argue that the MDA chose an inadequate approach.

In 2003 Senator Carl Levin "expressed grave concern" about the Bush administration's plans to field a missile defense capability in 2004, stating that "the missile defense system the administration plans to field . . . will not be fully tested or proven to work under realistic conditions" and that it "won't contribute to the defense or security of our country."[2] He reiterated these concerns six years later during his address to a missile defense conference.[3]

Lewis, Postol, and Levin are not against the missile defense mission; in fact Lewis and Postol adamantly maintain that a dire ballistic missile threat exists.[4] For Senator Levin, the issue concerned a decision to deploy a defensive system without sufficient, realistic testing. For these men, the MDA's failure to provide a convincing technical explanation of how the system will identify and hit incoming enemy warheads under expected combat conditions, or demonstrate such capabilities in realistic testing, had undermined their confidence in the ballistic missile defense system (BMDS). After the GMD test failure in December 2010, even optimistic supporters expressed concern over the system's performance.[5]

The mission is obvious—defeat the threat that current and future ballistic missile systems pose to our homeland, deployed forces, and allies.[6] The question is *how* to perform that mission, but it is not simply a matter of physics. The details of detecting, tracking, intercepting, and destroying a ballistic missile or warhead are fairly well defined. *However, defeating these missile threats in a cost-effective manner with neither advanced warning nor carefully controlled test preparations poses a challenge*. If we do it right, we assure our allies and deter our adversaries. If we do it wrong, we waste precious defense resources and delude ourselves with false confidence during crises. If we do it very well, we may be able to build ties with prior adversaries and dissuade future ones from pursuing ballistic missile weapons.

In the decade following the decision in 2001 to deploy GMD, the MDA investigated several alternative concepts but always concentrated development activities on large, surface-based interceptors. These decisions, made without the usual participation of the military services in requirements development, have resulted in very large interceptors simply too expensive to test frequently enough to inspire statistical confidence in their operational performance. For example, to date we have spent over $35 billion on the GMD system to provide a system with an alert force of 30 interceptors, with 16 additional ones for spares and testing.[7] Costs for the most recent test involving a single target and one interceptor likely exceeded $300 million.[8] The same large interceptor size that drives high unit costs also severely limits mobility and prompts deployment decisions not subject to quick alterations, thus increasing the system's vulnerability to unexpected adversary actions. In contrast, a concept of operations (CONOPS) emphasizing an air-launched interceptor would enable much smaller, less expensive interceptors that we could deploy quickly, opening options for boost- and terminal-phase intercepts not possible with a surface-based CONOPS.

To better understand today's missile defense systems, we need to consider the impact of the 1972 Anti-Ballistic Missile (ABM) Treaty.[9] Carefully written by US and Soviet negotiators who feared that effective ballistic missile defenses would lead to an arms race and even greater deployment of nuclear weapons, the ABM Treaty constrained the capabilities of any system that could alter the strategic balance. The treaty limited defenses against ICBMs to a single ground site, restricted the number and capability of defensive sensors, and precluded theater missile defense systems capable of engaging long-range ballistic missiles.[10] When Pres. George W. Bush withdrew the United States from the treaty, he removed those restrictions, but the concept and design underlying the current GMD system had already been set, and the initial system acquisition was already under contract. The United States had committed to deploying a defensive system compliant with the ABM Treaty yet capable of defending the entire country against missiles launched from North Korea. However, developers needed to solve the problem of midcourse discrimination between warheads and decoys—an impossible task, according to Lewis and Postol.[11]

Alternatively, they suggest intercepting missiles during their boost phase (fig. 1), using a relatively small interceptor carried by a low-observable, remotely piloted aircraft. In fact, their proposed interceptor is very similar to the air-launched hit-to-kill (ALHK) upper-tier interceptor previously studied by a joint Air Force–MDA team.[12] The ALHK concept builds upon previous concepts of air-launched interceptors explored under the Raptor-Talon program and, most notably, by the work of Dean Wilkening in 2004.[13]

Today's Missile Defense Systems

Today's BMDS works in both the midcourse phase (GMD, Aegis SM-3, and theater high-altitude area defense) and the terminal phase (theater high-altitude area defense, Patriot advanced capability three, and Aegis SM-2 Block 4) (see fig. 1). The airborne laser was intended to destroy ballistic missiles in the boost phase, but the acquisition program was cancelled in 2009.[14] Despite the lure of engaging targets at the speed of light, concerns about high unit cost, countermeasures, and operational limitations led the secretary of defense to focus BMDS developmental efforts on maturing directed-energy technology prior to resuming acquisition of the airborne laser system. Also intended to provide a boost-phase capability, the kinetic energy interceptor, despite its large size (40 feet long, 40 inches in diameter, and 25,000 pounds), fast acceleration, and high speed, still needed to be located relatively close to launch areas to catch ballistic missiles during that phase.[15] Earlier manage-

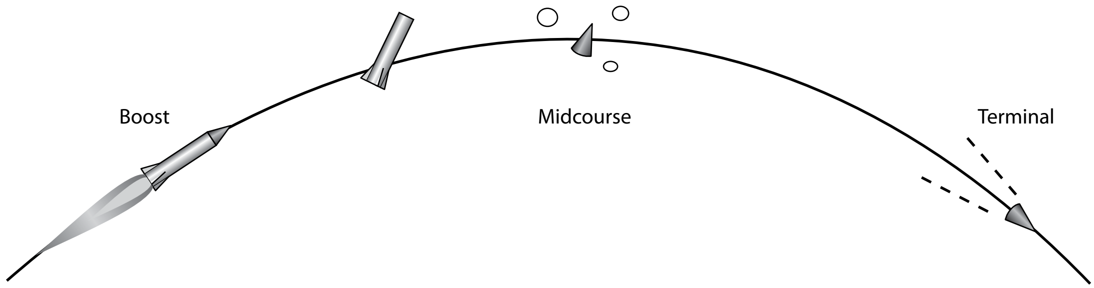


Figure 1. Phases of a ballistic missile's flight

ment decisions had focused this interceptor solely on booster development, but further cutbacks terminated the program in 2009.[16]

All missile defense systems depend on sensors to track their targets precisely, and in most cases (except the kinetic energy interceptor, which planned to rely on existing missile warning satellites and the airborne laser, which carried an Infrared Search and Track System [IRSTS]) these sensors are large, surface-based radars.[17] Such radars offer a persistent and highly accurate tracking capability, but they are either fixed on the ground or floating at sea; furthermore, the transportable ones require significant airlift capacity. These sensors are also vulnerable to adversary attack, and any loss can disable a large number of associated interceptors. In the case of GMD, data from the radars must be sent to the fire-control computers located in either Alaska or Colorado, and in-flight updates go out to the kinetic kill vehicle. Data transfer alone makes use of multiple, potentially vulnerable communication links.[18]

The Missile Defense Agency's Development Plans

In 2009 the MDA made significant changes in its advanced technology efforts, terminating ALHK as well as other technology explorations and concentrating developmental efforts on larger, higher-velocity, and longer-range derivatives of the Aegis SM-3.[19] In addition, the agency adjusted the objectives of its long-enduring, space-based sensor development, seeking a smaller constellation of satellites in equatorial orbits.[20] Airborne infrared tracking sensors carried on remotely piloted aircraft systems were added to support earlier intercepts and take advantage of the planned longer-range SM-3 interceptors.[21]

Plans for a European GMD deployment were scrapped in favor of a land-based deployment of SM-3 interceptors, emphasizing wide-area defense of Europe but having midcourse-only capability. This new plan, the Phased Adaptive Approach, starts with a deployment of Aegis ships carrying SM-3 interceptors, followed by augmentation with forward-deployed radars, and ends with a ground-based SM-3 currently under development. Later, the longer-range SM-3 Block 2A, currently planned as a 21-inch-diameter "full caliber" missile, would upgrade deployments, as would a liquid-fueled upper stage in the SM-3 Block 2B.[22]

Deployment of the SM-3 Block 2B would regain the midcourse intercept capability against Iranian ICBMs that we lost with cancellation of the European GMD detachment, but many challenges remain.[23] The Navy does not intend to put liquid-fueled interceptors on board ships, and the Army has no interest in a land-based variant of the SM-3.[24] Additionally, what, if anything, Europe would contribute to this defense concept has yet to be resolved. Finally, Russia remains highly skeptical of plans that could threaten its nuclear deterrent capability in the future or that would deploy US forces along its borders.[25]

The Air-Launched Hit-to-Kill Alternative

In late 2009, the US Air Force and the MDA completed a joint study on the viability of ALHK against regional ballistic missile threats, declaring the concept technically feasible and operationally viable. Initial war game analysis showed the usefulness of ALHK, including desirable effects on secondary metrics such as sortie-generation rates of theater aircraft, even though many details remain unverified. The initial study emphasized both classes of interceptors (upper and lower tier), supported by an IRSTS carried by the launching aircraft.[26] A follow-on joint Airborne Weapons Layer study is in progress, but the MDA has committed no resources or even restored those previously cancelled. The Air Force, in contrast, has expressed significant interest in the program and is continuing limited follow-on studies at Eglin AFB, Florida.

The ALHK components briefly described here include a lower-tier interceptor modeled with a 1.75 kilometer per second (km/sec) burnout velocity that primarily uses aerodynamic maneuvering, possibly supplemented with divert thrusters. It can generate 10 g's of lateral acceleration at a 20 km altitude, but its agility decreases rapidly above that altitude. Roughly the size of an AIM-120 advanced medium-range air-to-air missile, it is carried in the same manner.[27] The upper-tier interceptor, modeled with a 3.5 km/sec burnout velocity, uses divert thrusters for all maneuvers following booster burnout. Capable of 10 g's of lateral acceleration, it can engage only above 50 km altitude due to seeker heating limitations.[28] Roughly four times the weight of the advanced medium-range air-to-air missile but not much longer, the upper-tier interceptor fits within the F-35's internal weapons bay. Moreover, fourth-generation fighters could carry it externally.[29]

The supporting IRSTS pod could resemble the Sniper or Litening, with 20 centimeter optics carried externally, or an integral internal system such as the F-35's Distributed Aperture System—or both. It lends itself to integration with the aircraft radar, or it can work in pairs via triangulation, depending upon the weapon (upper tier or lower tier) supported, the phase of intercept (boost, ascent, or terminal), and the engagement range.[30]

The Distributed Aperture System is of particular interest due to its complete coverage in every direction around an F-35 and because it will be standard equipment on each F-35 produced. On 4 June 2010, a test aircraft equipped with this system detected and tracked the entire boost phase of a Falcon 9 space launch vehicle from well in excess of the maximum kinematic range of an upper-tier interceptor.[31] The system's small aperture will limit its range when tracking in the postboost or terminal phases, but it may support uncued terminal intercepts at a short range with a lower-tier interceptor. If so, it would enable a relatively "stock" F-35 to provide autonomous terminal defense when equipped with a lower-tier interceptor. Future tests will reveal the system's actual capabilities.

Existing, demonstrated technologies support these systems although they are not yet integrated into a weapon system. Raytheon's Net-Centric Airborne Defense Element showed how a modified AIM-9X seeker head could track a boosting missile and discern its body in the presence of the rocket plume. It performed a successful boost-phase intercept in 2007 (the MDA's first) in just under three years and for a cost of roughly $25 million.[32] Significant development work lies ahead for the upper-tier interceptor in particular, but the fundamental, well-defined technology has been demonstrated in a relevant environment.

Air Sovereignty Alert

Interceptors, sensors, and aircraft are only part of the larger system. We propose incorporating these components with ASA aircraft on duty continuously around the United States. Although the number and locations of actual ASA sites undergo occasional adjustment, the basic distribution has remained fairly constant over the past five years.

The 16 alert sites within the continental United States and one each in Alaska and Hawaii (fig. 2) typically maintain two primary alert aircraft and a spare on "immediate" status. However, 14 of the 18 ASA sites are colocated with active duty or Air National Guard squadrons capable of rapid augmentation in the event of heightened tensions. Currently, we have a mix of F-15, F-16, and F-22 fighters on alert, but F-35s will begin to replace the older F-15s and F-16s in coming years.[33] The command and control system for ASA, a principal part of North American Aerospace Defense Command's (NORAD) Integrated Threat Warning and Attack Assessment system, features secure and redundant communications continuously linking missile warning sensors, air surveillance sensors, the national civil-

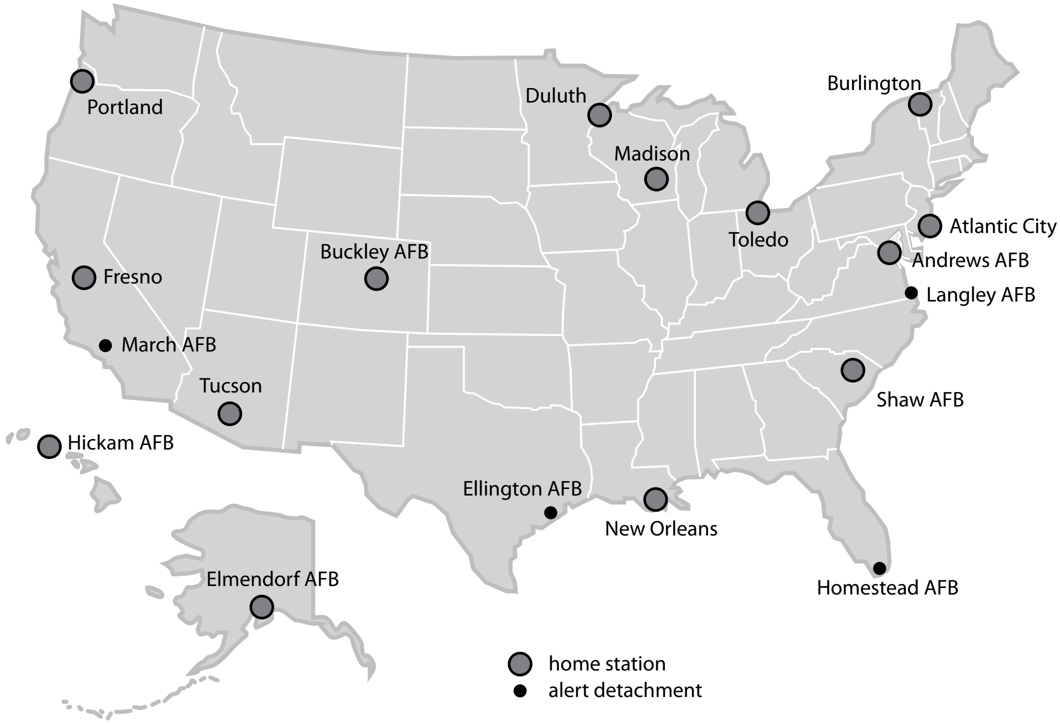


Figure 2. Steady-state air sovereignty alert sites (2008). (Adapted from Government Accountability Office, *Homeland Defense: Actions Needed to Improve Management of Air Sovereignty Alert Operations to Protect U.S. Airspace*, Report to Congressional Requesters, GAO-09-184 [Washington, DC: Government Accountability Office, January 2009], 13, fig. 3, http://www.gao.gov/new.items/d09184.pdf.)

ian air and space control system, and national decision makers.

Figure 2 depicts both home stations—sites colocated with their associated squadron—and detachments located at another base or airfield separate from the squadron. Originally planned following the terrorist attacks of 11 September 2001, these sites enable fighter aircraft to respond to the vicinity of most major metropolitan areas within 20 minutes.[34] This planning, driven by the threat of hijacked aircraft, also enables ASA aircraft to position themselves optimally during an ICBM's time of flight (30-40 minutes) to launch both upper- and lower-tier interceptors as terminal-phase defense of US territory. In the case of an ICBM launched on a minimum-energy profile from Iran against Washington, DC, the total flight time is slightly less than 33 minutes.[35]

The infrastructure at each ASA site includes aircraft shelters for at least four aircraft, security, living quarters for the pilots and maintenance personnel, and secure, redundant communications. These communication links include ties to the Eastern and/or Western Air Defense Sectors, which monitor the airspace, as well as the local airfield control tower and air route traffic control centers. The 601st Air and Space Operations Center at Tyndall AFB, Florida, plans and monitors all operations within the Continental NORAD Region, maintaining direct communication with NORAD/Northern Command headquarters.[36] Alaska supplies similar capabilities through the

Alaskan NORAD Region, as does Hawaii through Pacific Command.

The time required for the fighters to become airborne following a scramble order varies but usually takes on the order of six to seven minutes.[37] Given an unrestricted climb, fighters configured with two external fuel tanks, two upper- and two lower-tier interceptors, and an infrared tracking pod would typically need another five minutes to climb to an altitude of 15 km (approximately 48,000 feet) and accelerate to supersonic speed. Twelve minutes after a scramble order, the fighters would be 75 km away from their ASA launch base, moving in excess of 20 km per minute—a speed they could sustain for roughly 20 minutes before their fuel supply became a concern. Without performing a supersonic dash, fighters in this configuration could cruise for two hours or more before refueling.[38]

Homeland Defense Scenarios

Two scenarios illustrate potential real-world applications of the proposed ALHK system.

Scenario One

Intelligence analysts receive indications that an adversary plans to launch a ballistic missile from a ship, resulting in a high-altitude detonation of a nuclear weapon over the US east coast. The enemy anticipates that the resulting electromagnetic pulse will disrupt communication and power transmission in major metropolitan areas. He might wish to demonstrate a nascent nuclear capability to deter US involvement in a pending theater conflict or disrupt US force deployments without actual killing or destruction.[39]

Given the threat as described, we would use all of the nation's technical capabilities to find the ship. However, even if we locate it, the vessel could still launch a ballistic missile. For example, transporting a US boarding party to the vicinity may require days. In the interim, the ship could launch a missile once it enters the ellipse depicted

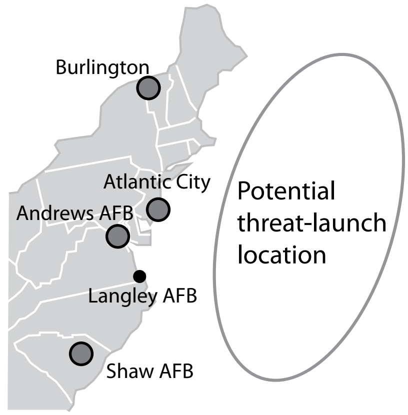


Figure 3. Scenario one: sea-launched ballistic missile threat

in figure 3. After US forces find the ship, they could always sink it with an air strike, but without boarding and inspecting it, we cannot know the intentions of the ship with certainty. Since the scenario postulates a high-altitude electromagnetic pulse attack, terminal defenses would not help even if we knew a specific target and could deploy our defenses in time.

Simulating engagement of the threat with an upper-tier interceptor shows that the maximum employment range depends upon the time interval between the threat launch and interceptor launch. The high-altitude electromagnetic pulse scenario constrains the planning to require an intercept no later than 100 seconds after the threat launch.[40] Using existing weather conditions to predict infrared detection (i.e., a cloud-free line of sight between the threat and the fighter) and sufficient tracking time to determine a threat-state estimate (roughly five seconds) prior to launching the interceptor, planners calculate maximum engagement ranges and determine engagement zones for the expected threat region.[41]

Planners use these engagement zones to develop a combat air patrol (CAP) plan that covers the potential threat-launch area. The center of each ellipse in figure 4 roughly represents a CAP point for a single fighter.

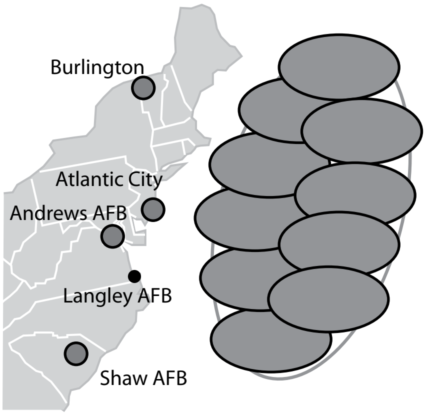


Figure 4. Defense plan for scenario one

Fighters launch from the ASA sites indicated on the map and proceed to the CAP points.

Simultaneously, the Air National Guard squadrons at Burlington, Vermont; Toledo, Ohio; Andrews AFB, Maryland; and Atlantic City, New Jersey, mobilize and, along with the active duty squadron at Shaw AFB, South Carolina, begin preparing additional aircraft for launch. Tanker aircraft on one-hour alert are launched to refuel the alert fighters at the CAP points. After roughly six hours, new fighters launch to replace those on station. This operation could continue for a week or longer if necessary to find and neutralize the threat ship or to determine whether or not it is in the predicted launch area.

Scenario Two

Fighters are on normal ground alert at each indicated ASA site when an ICBM launch from Iran occurs without warning. Initial detection by infrared missile-warning satellites prompts a "quick alert" warning before the missile completes its boost phase. Although tracking accuracy is not yet sufficient to estimate the ICBM's actual target, it does indicate a missile type capable of reaching the United States and an initial azimuth toward the US east coast. At that point, fighters at their bases (fig. 5) receive a scramble order. As the ICBM finishes its boost phase, it also rises above the horizon, as viewed from the Fylingdales space surveillance radar located in the United Kingdom, and a radar track begins. At this point, when it becomes clear the missile is headed toward Washington, DC, a state estimate of the ICBM along with its probable impact point passes through the NORAD system to the scrambling ASA aircraft.

The fighters take off roughly 10 minutes after the ICBM launches and receive the latest ICBM tracking update by data link at roughly the same time. Onboard systems for each of the fighters then calculate an optimal launch point for upper-tier interceptors, and the planes from Toledo and Shaw AFB proceed in a supersonic dash toward their interceptor launch points (fig. 5). Fighters from Langley AFB, Virginia; Andrews AFB; Burlington; and Atlantic City climb and then loiter near their planned launch points. If the threat enters the field of view of the space-surveillance radar sites at Thule, Greenland, and Cape Cod, Massachusetts, updated ICBM tracking information passes to the fighters, again by data link, to refine the interceptor aircrafts' targeting solutions.

Simulations with the upper-tier interceptor show an acceptable interceptor launch area of about 1,000 km cross range and 1,500 km up range from the intended target, an area that 10 of the 12 fighters have reached 15 minutes after their takeoff. Operating at 15 km altitude, well above any clouds, the fighters focus their IRSTS on a search pattern around the predicted position of the threat. At the optimum time, each fighter launches two upper-tier interceptors about 10 seconds apart toward predicted intercept points as the aircrew continues to scan with the IRSTS. As the threat warhead, upper rocket body, and decoys reenter the atmosphere, they begin to heat up, and the IRSTS rapidly detects them. Using intensity patterns and, possibly, spectral signatures observed by the IRSTS to identify potential reentering warheads, the fighters uplink the target designation to the upper-tier interceptors.

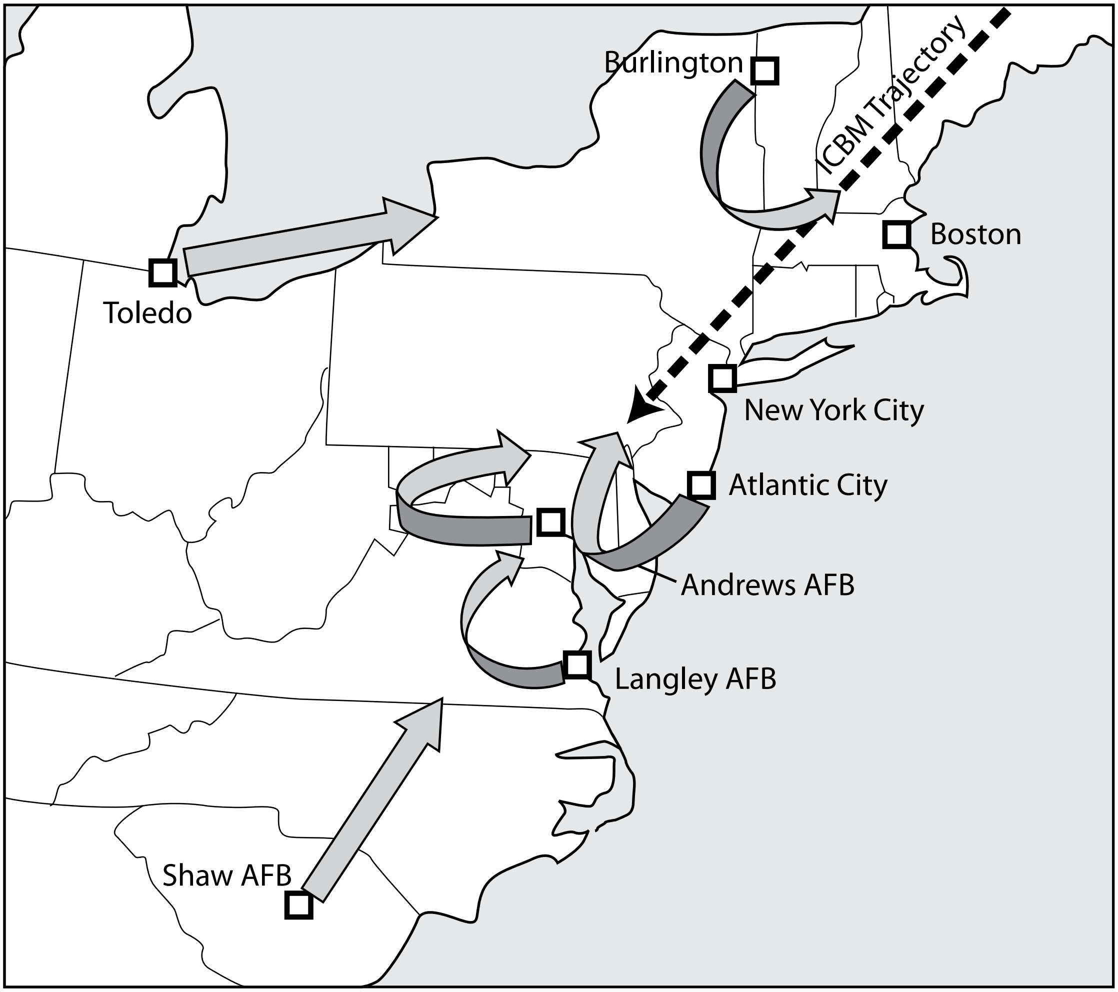


Figure 5. Initial ASA response to Iranian ICBM launch (scenario two)

The geographic areas plotted in the upper part of figure 6 represent the allowable interceptor launch points for an upper-tier interceptor intended to intercept at 100 km altitude (left) and 50 km altitude (right). The region between these altitudes represents the desired intercept zone, characterized by optimal atmospheric interaction for identifying the warhead; moreover, in this area, seeker heating does not require significant cooling measures, and one can avoid atmospheric jet interaction, which complicates maneuvering.[42] This is the "heart of the envelope" for the upper-tier interceptor in a terminal intercept.

The area depicted at the bottom of figure 6 shows allowable interceptor launch points for an exoatmospheric (i.e., midcourse) intercept using only BMDS sensor data. All simulations were limited to ascending interceptor flight paths, but this zone would still have a lower probability of success for the upper-tier interceptor.

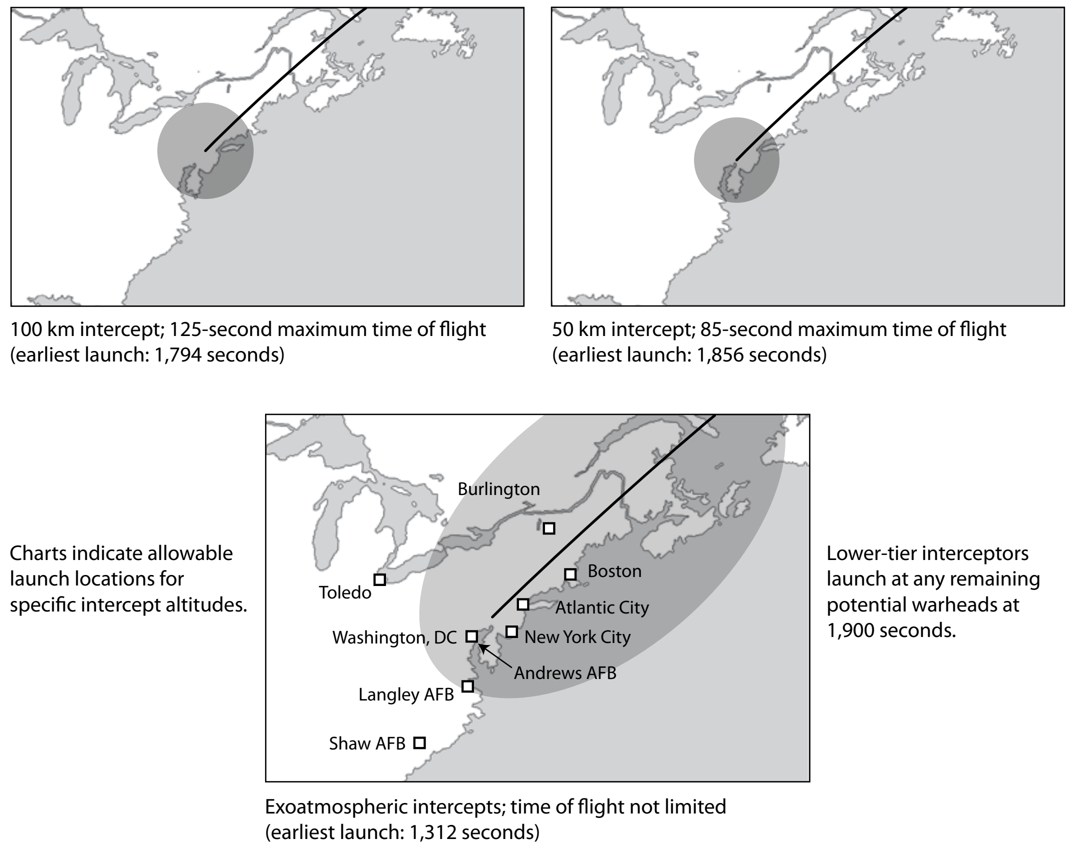


Figure 6. Simulation results for scenario two with upper-tier interceptor. "Earliest launch" measures the time since the ICBM's launch. For example, the lower graphic shows that aircrews may not launch upper-tier interceptors for an exoatmospheric intercept sooner than 1,312 seconds into the ICBM's flight.

Although the differential response to atmospheric heating of individual elements associated with the reentering ICBM provides the principal discriminant for upper-tier engagements, deceleration of reentering objects due to atmospheric drag becomes another discriminating factor for a lower-tier engagement yet also increases the difficulty of performing hit-to-kill intercepts. The midcourse phase of an ICBM's flight diminishes the chances of distinguishing lightweight decoys from the real warhead. Conversely, the terminal phase makes it difficult for those decoys to display the same deceleration profile and thermal response to atmospheric friction as the actual warhead. In essence, finding the right target becomes easier during the terminal phase, but intercepting it becomes harder.

Intercepting an ICBM during the terminal phase can prove challenging because of the missile's tremendous deceleration (more than 50 g's). This deceleration can appear as an evasive target maneuver to the pursuing interceptor. However, on near-inverse trajectories between the interceptor and target, the pursuing interceptor does not see this apparent maneuver, thus making interception possible. Therefore, the challenge in terminal intercepts of ICBMs lies in getting the interceptor on these near-inverse trajectories—which only an air-launched interceptor can do consistently.

A typical ICBM warhead encounters 20 g's of deceleration at 20 km altitude, growing to over 50 g's at 10 km (fig. 7). With a high aspect angle, very little acceleration occurs perpendicular to the interceptor's flight path, enabling even the relatively low lateral acceleration of lower–tier interceptors to engage an ICBM warhead successfully at 20 km altitude.[43] In fact, the authors' simulations show that using only proportional navigation, without requiring ranging to the warhead, allowed lower-tier interceptors to engage successfully at a 20 km intercept altitude if launched within 70 km of the warhead's target—and at a 10 km intercept altitude if launched within 30 km.[44]

During the scenario, fighters from Langley AFB, Andrews AFB, and Atlantic City position themselves within 70 km of the ICBM's intended target (Washington, DC) during the time between their scramble order and the time when they should launch lower-tier interceptors at any incoming warhead that survives the upper-tier engagement.

Figure 8 is a quantitative depiction of the engagement opportunities. Twelve aircraft have scrambled from six separate locations, each plane carrying two upper-tier and two lower-tier interceptors. Ten fighters launch both their upper-tier interceptors, eight of those intercepting the ICBM between 50 and 100 km altitude. Six of these fighters follow by firing two lower-tier interceptors each, yielding a total of 32 possible intercept opportunities. The fighters from Shaw AFB do not reach an acceptable launch point in the time available.

The actual number of interceptors launched in such a scenario depends on

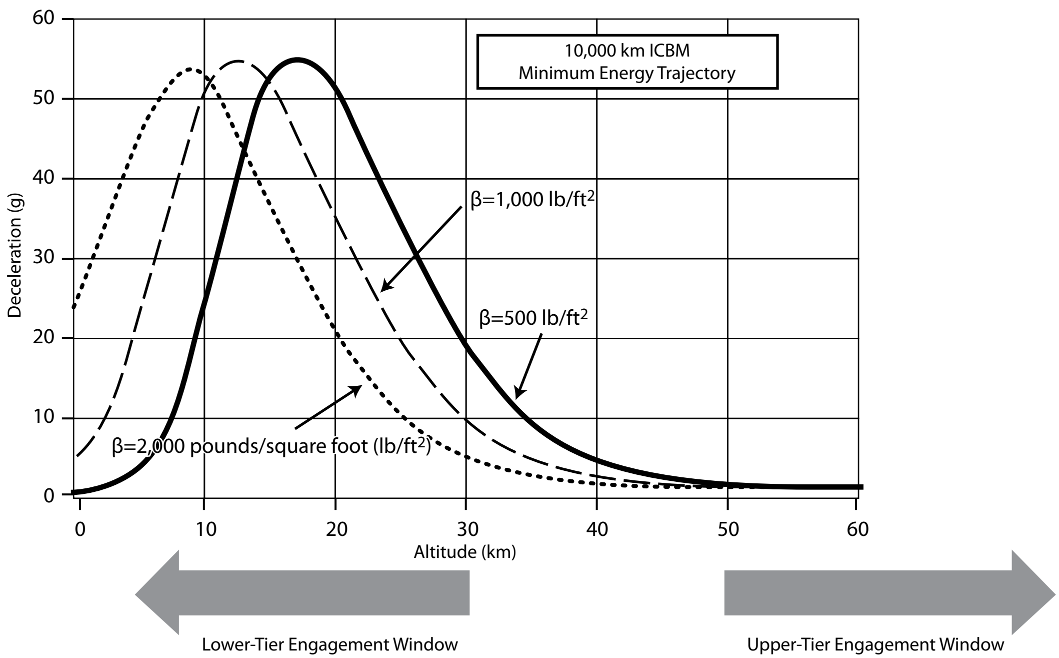


Figure 7. ICBM deceleration profile. Beta (β) refers to a characteristic used to estimate deceleration due to aerodynamic drag. Large β numbers indicate objects that have greater density, less drag, or both. Warheads have a high β number while decoys like balloons or chaff have a very low number.

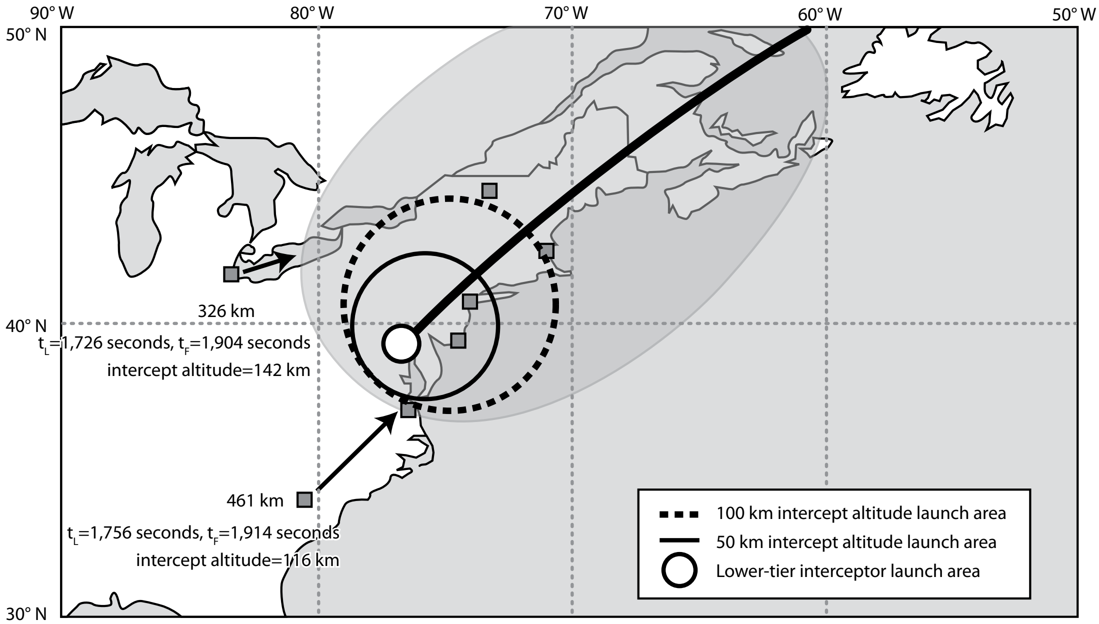


Figure 8. Simulation summary of scenario two. Notations at Toledo and Shaw AFB represent distances to the nearest launch point, elapsed time from the ICBM launch for the planes to arrive and launch upper-tier interceptors (t_L), time from the ICBM launch to the intercepts (t_F), and intercept altitudes.

many factors, including whether we anticipate another ICBM attack and whether the flight of one interceptor might conflict with that of another. However, given the scenario described, all interceptors would probably launch unless we firmly believed that all possible warheads were destroyed prior to the last launch opportunity. In light of preliminary estimates for both upper- and lower-tier interceptors, the total cost of all 32 interceptors would be less than the cost of two of today's GMD interceptors.[45]

What Does All of This Mean?

Distinct probabilities are associated with an aircraft scrambling with all required systems functioning and continuing to function throughout the intercept, the interceptor launching with all systems functioning, and so forth. We can estimate these probabilities analytically but can *determine* them definitively only through realistic operational testing. The Air Force continuously evaluates its planes, pilots, and air-to-air missile systems though a realistic weapon system evaluation program known as Combat Archer, which tests roughly 300 missiles per year and tracks these probabilities for each weapon system.[46] In contrast, the MDA conducted just seven flight tests of hit-to-kill ballistic missile intercepts between October 2008 and April 2010; of those, only two were GMD and only one GMD interceptor hit the target during that period.[47]

ASA aircraft equipped with ALHK would build on the existing US air defense infrastructure and enable homeland defense that we could deploy in minutes if necessary. Compatible with our current fourth- and fifth-generation fighters, this system would provide a terminal-phase layered approach to complement GMD. It would integrate well with the mission and capabilities of the Air National Guard, providing a baseline alert response for surprise threat launches that we can augment by mobilization for heightened homeland defenses or expeditionary deployment.

Because of the interceptor missiles' small size, they cost much less than GMD, perhaps on the order of 5 percent of the unit cost per interceptor.[48] This cost advantage enables higher production rates, which in turn lowers unit expenses even further, which allows more frequent testing, which increases confidence in the system's operational performance.

Imagine our combining the periodic Minuteman "Glory Trip" reliability tests with ALHK operational tests and deploying fighters to Kwajalein or Guam for quarterly employment tests.[49] Imagine the confidence that would build—and for very little additional cost.

System development, like system confidence, must begin with consensus on the CONOPS, with key decisions belonging to the combatant commanders. In most weapon acquisitions, the Joint Capabilities Integration and Development System (JCIDS) establishes the CONOPS and key performance requirements, and the Joint Requirements Oversight Council closely oversees the derived requirements.[50] The MDA, however, has operated with a waiver from the JCIDS process, which allows it to make system acquisition decisions involving cost, schedule, and performance independently of the military services, with oversight by the Missile Defense Executive Board.[51] The *Ballistic Missile Defense Review Report* of 2010 found no benefit in bringing the MDA into the JCIDS or into the full Department of Defense 5000 acquisition reporting process at this time.[52] However, that review also concluded (perhaps prematurely) that the United States currently enjoys protection against limited ICBM attacks.[53]

ALHK could contribute capabilities to other missions beyond missile defense that this article does not address, including very-long-range counterair, electronic countermeasures, very-long-range visual identification, suppression of enemy air defenses, and even space control in low Earth orbit. We need to make decisions regarding trade-offs in these areas from a broader perspective than solely that of missile defense. The *Ballistic Missile Defense Review Report* noted the benefit of further innovation in managing the missile defense program and the fact that the Department of Defense is pursuing the creation of additional hybrid MDA/service program offices.[54] Such a concept could work well with a potential ALHK acquisition, provided the services have a bigger voice in missile defense acquisition programs. To do so and to improve the program's results, the MDA should relinquish its JCIDS waiver and follow the full DOD 5000 acquisition reporting process.

Conclusion

The ability to respond quickly and flexibly to a wide variety of potential adversary developments is critical to preventing any defensive CONOPS from becoming the twenty-first-century equivalent of the Maginot Line. Despite the persistence of fixed defensive establishments, a variety of forces can target them or, as in the case of the Maginot Line, simply avoid them. From the military perspective, enduring value depends upon the ability of any ballistic missile defensive system to respond with little notice and provide capability in a variety of scenarios. As shown in an earlier article by the authors, the ALHK concept would also work against theater missile threats.[55] Allies could participate with their own aircraft, allowing them to make their own investments—in affordable increments—for their own defense.

We gain confidence in a system's effectiveness through reaching consensus on the underlying principles in the CONOPS and through conducting rigorous operational testing in which the operator has no control over the test environment. It is not fiscally possible to obtain statistical confidence in an operational environment when a single test costs over $200 million, but frequent testing with a much less expensive small air-launched interceptor would generate a high degree of confidence.[56]

Building a missile defense system that inspires confidence starts with a CONOPS grounded in accepted physical principles, demonstrated technology, and war-fighter needs. It progresses with needs optimized from the combatant commander's perspective, balanced against realistic estimates of the cost of development. It then requires competitive prototypes that have undergone sufficient developmental testing to verify the contractor's approach and a commitment to full developmental funding. Finally, it demands competitive source selection and initial production rates sufficient to demonstrate operational performance. Following initial operational capability, it requires an ongoing commitment to incremental improvements and continued operational testing to ensure that confidence remains as systems age and adversaries adapt.

We should reexamine not only the MDA's decision to focus all development funding on midcourse interceptors but also *the decision process itself*. ALHK may not be the best answer, but it represents a path to a system that could build confidence, thus warranting continued development. ✪

Notes

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12. Sam LaGrone, "Fighters Eyed for Ballistic Missile Defense," *Air Force Times*, 16 June 2009, http://www.airforcetimes.com/news/2009/06/airforce_fighter_missile_061609w/.

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national Institute for Strategic Studies, May 2000). For the challenges of boost-phase intercepts, see the excellent unclassified work *Report of the American Physical Society Study Group on Boost-Phase Intercept Systems for National Missile Defense: Scientific and Technical Issues* (College Park, MD: American Physical Society, 5 October 2004), http://www.aps.org/about/pressreleases/upload/BPI_Report.pdf. The American Physical Society's threat models are the same ones we use in this article to demonstrate ALHK capabilities. For a more detailed treatment of ALHK components, see Col Mike Corbett, USAF, retired, and Paul Zarchan, "The Role of Airpower in Active Missile Defense," *Air and Space Power Journal* 24, no. 2 (Summer 2010): 57–71.

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27. Ibid., 65.

28. Infrared seekers typically work best at cryogenic temperatures. Atmospheric friction would heat the seekers, degrading their effectiveness.

29. Corbett and Zarchan, "Role of Airpower," 65–66.

30. Ibid., 66.

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33. Government Accountability Office, *Homeland Defense: Actions Needed to Improve Management of Air Sovereignty Alert Operations to Protect U.S. Airspace*, Report to Congressional Requesters, GAO-09-184 (Washington, DC: Government Accountability Office, January 2009), 27, http://www.gao.gov/new.items/d09184.pdf. This report also contains additional details on ASA infrastructure.

34. Colonel Corbett's firsthand experience in operations after 11 September 2001 as the vice-commander, First Air Force, from 2000 to 2003.

35. Corbett and Zarchan, "Role of Airpower," 58.

36. "601st Air and Space Operations Center," First Air Force, http://www.1af.acc.af.mil/units/601staoc/index.asp.

37. Thomas H. Kean et al., *The 9/11 Commission Report: Final Report of the National Commission on Terrorist Attacks upon the United States* (Washington, DC: US Government Printing Office, 2004), 20–27, http://govinfo.library.unt.edu/911/report/911Report.pdf. This document discusses the response times for fighters scrambled during the terrorist attacks of 11

September 2001. Although the open literature refers to an immediate readiness posture of 15 minutes, alert fighters typically do much better. On 11 September 2001, fighters from Otis Air National Guard Base, MA, were airborne in seven minutes, and those from Langley AFB, VA, in six minutes.

38. See performance data referenced to Technical Order 1F-15C-1 and TO 1F-16C-1 (dash one) performance tables for representative drag indices and nominal atmospheric temperatures.

39. The difficulty of predicting an adversary's reasoning and subsequent actions lies outside the scope of this article. We intend only to demonstrate how ASA aircraft equipped with ALHK could counteract such a threat.

40. Scott Stewart and Nate Hughes, "Gauging the Threat of an Electromagnetic Pulse (EMP) Attack," STRATFOR, 9 September 2010, http://www.stratfor.com/weekly/20100908_gauging_threat_electromagnetic_pulse_emp_attack.

41. A threat-state estimate is a measurement of the threat missile's position, velocity, and acceleration at a specific point in time. Once the missile is past the boost phase, this estimate can be used to accurately predict the missile's target as well as its location in flight.

42. "Atmospheric jet interaction" refers to the complex forces resulting from divert thrusters firing into high-speed atmospheric flow around the interceptor, at times creating adverse accelerations.

43. "Aspect angle" refers to the angle between the warhead's flight path and the interceptor's flight path. High aspect angles approach 180 degrees, indicating a head-on engagement.

44. Proportional navigation is a form of interceptor guidance that requires only the relative bearing from the interceptor to the target for determining guidance commands. In essence, the interceptor seeker observes a change in the line of sight between it and its target and maneuvers a "proportional" amount in the direction of that observed movement. When the relative movement in line of sight ceases, the interceptor is on a collision course with its target.

45. Corbett and Zarchan, "Role of Airpower," 67.

46. "53rd Weapons Evaluation Group," fact sheet, 9 June 2009, Tyndall AFB, FL, http://www.tyndall.af.mil/library/factsheets/factsheet.asp?id=4892.

47. House, *Lieutenant General Patrick J. O'Reilly, USA, Director, Missile Defense Agency, [Testimony] before the House Armed Services Committee, Strategic Forces Subcommittee, April 15, 2010*, 111th Cong., 2nd sess., 11, http://www.mda.mil/global/documents/pdf/ps_hasc041510.pdf.

48. Corbett and Zarchan, "Role of Airpower," 67.

49. The "Glory Trip" program entails the Air Force's removing operational ballistic missiles from their silos, removing their warheads, and shipping the missiles to Vandenberg AFB, CA, for a test launch. The Air Force does this about once per quarter to demonstrate ICBM system reliability.

50. *Wikipedia: The Free Encyclopedia*, s.v. "Joint Capabilities Integration Development System," accessed 1 February 2011, http://en.wikipedia.org/wiki/Joint_Capabilities_Integration_Development_System.

51. Government Accountability Office, *Defense Management: Key Challenges Should Be Addressed When Considering Changes to Missile Defense Agency's Roles and Missions*, GAO-09-466T (Washington, DC: Government Accountability Office, 26 March 2009), 2, http://www.dtic.mil/cgi-bin/GetTRDoc?Location=U2&doc=GetTRDoc.pdf&AD=ADA495698. This document includes testimony by John H. Pendleton, director of defense capabilities and management, before the Strategic Forces Subcommittee, Committee on Armed Services, House of Representatives.

52. Department of Defense, *Ballistic Missile Defense Review Report*, 43. The Defense Acquisition System is the management process that guides all of the Department of Defense's (DOD) acquisition programs. DOD Directive 5000.01, *The Defense Acquisition System*, 12 May 2003, includes policies and principles that govern the defense acquisition system. DOD Instruction 5000.02, *Operation of the Defense Acquisition System*, 8 December 2008, in turn establishes the management framework that implements these policies and principles. The Defense Acquisition Management Framework provides an event-based process by means of which acquisition programs proceed through a series of milestones associated with significant program phases. See sec. 3 of the instruction for details on the milestones and program phases. The instruction also identifies the specific statutory and regulatory reports as well as other information requirements for each milestone and decision point. The MDA is waived from these requirements until milestone C, the point at which a weapon system receives approval to enter production. See "DoD 5000 Defense Acquisition System," Defense Acquisition Portal, accessed 19 April 2011, https://dap.dau.mil/aphome/das/Pages/Default.aspx.

53. Department of Defense, *Ballistic Missile Defense Review Report*, 15.

54. Ibid., 43.

55. Corbett and Zarchan, "Role of Airpower," 62–64.

56. House, *Lieutenant General Patrick J. O'Reilly*, 39.

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