



## Exploiting Airpower's Missile Defense Advantage: The Case for Aerial Boost Phase Interception

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### Abstract

Increasingly complex and capable ballistic missiles being fielded by potential US adversaries call for the urgent development of an aerial boost phase intercept (ABPI) capability for the US Air Force and US military services. This paper outlines new proposals for an ABPI interceptor design that could allow the Department of Defense (DOD) to deploy an ABPI emergency capability within two years, and an objective capability within four years.

A near-term emergency adaptation involves altering existing AIM-9 and AIM-120 air-to-air weapons to shoot down ballistic missiles in boost phase, seconds after launch. Early modifications would involve little more than new software and coding to enable these proven capabilities to better target and intercept ballistic missiles. Other modifications could include divert and attitude control adjustments that allow the interceptor missile to maneuver better outside the atmosphere.

An objective ABPI weapon would also be approximately the same size as the AIM-120, allowing it to be carried onboard fighter aircraft, and even remote piloted aircraft systems (RPA). This paper advocates for an ABPI capability that is platform agnostic, while realizing that some systems and aircraft have compelling advantages.

In sum, a capable ABPI system would relieve the engagement burden on the existing missile defense system, help thin potential missile raids, decrease the destructive potential of ballistic missile attack, and bolster the deterrent of US missile defenses.

## **Introduction: The Need for Aerial Boost Phase Interception**—

On November 29, 2017, North Korea launched a missile that flew a distance of around 590 miles, reaching an altitude of approximately 2,796 miles before impacting in the Sea of Japan. A short time later, North Korea state media announced its military had launched a new weapon—the *Hwasong-15* (HS-15)—capable of delivering a “super-large heavy warhead” to anywhere within the United States.<sup>1</sup> In the aftermath of the event, experts from various US agencies and outside analysts agreed that the North Korean statement, based on radar track data of the missile, was factually valid.

This successful launch represents a substantial challenge to US security, insofar as a credible threat of aerial attack now exists from North Korea that may not be sufficiently mitigated by conventional or US nuclear deterrent forces. The US Department of Defense’s (DOD) response to this new capability must be a focused, swift, multi-service development program to field an effective boost phase intercept ballistic missile defense (BMD) system.

Defense Secretary James Mattis stated that “...if we fail to adapt...at the speed of relevance, then our military forces and our Air Force will lose the very technical and tactical advantages we’ve enjoyed since World War II.”<sup>2</sup> Considering North Korea’s November 2017 missile test, the challenge could not be clearer.

The speed of relevance, for the purposes of this paper, is defined as reasserting America’s technical capabilities to allow its military airpower to confront the challenge posed by a North Korean intercontinental ballistic missile capable of striking the US homeland. America currently has no air-based operational kinetic weapons designed to shoot down ballistic missiles. The US military faces an urgent need to rapidly innovate and field an emergency capability—specifically an aerial boost phase interception (ABPI) capability.

The best path to developing a kinetic counter to the threat from North Korean missiles is to look toward airpower theory for a potential solution, then to examine previous ABPI analysis. Next, ABPI capability developers should look at the capabilities of existing air-to-air weapons and aircraft to discern where kinetic engagement can be implemented. This will lead to the adaptation of existing weapons, and development of some new weapons. The DOD and the US military services must field these weapons by using pioneering technology and solid engineering, and merge these attributes with sound operational tactics, techniques, and procedures. The US Air Force, US Navy, and US Marine Corps must also create new training regimens and programs for aviators, to enhance their ability to shoot down ballistic missiles in boost phase—an important step in creating the infrastructure to sustain an ABPI capability.

## **Technology Solutions Within Reach: The Crux of the ABPI Case**—

This paper argues that the relevant scientific and technological challenges are not intractable with regards to missile defense, and lie within the DOD’s ability to solve. US tactical military airpower (manned and or unmanned) with modest onboard equipment enhancements combined with adapted and battle-proven air-to-air weapons, can provide reinforcement of American missile defenses and pave the way towards developing optimized aerial weapons and sensors, making the missile defense enterprise more robust and resilient.

The diversity, quantity, and aggregate combat power of Air Force sensors and shooters best address the ballistic missile defense capability gap to meet an urgent need. Airborne kinetic capabilities will provide two additional engagement layers through boost phase engagement, and an underlying terminal engagement opportunity to augment the US ground-based midcourse defense (GMD) system, now deployed in Alaska and California and capable of intercepting ballistic missiles. Determining the size of a mature ABPI system is beyond the scope of this paper. However, an inventory of 300-500 ABPI interceptor missiles might satisfy immediate deterrence needs and

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short-term combatant commander demand for boost phase engagement in forward regions, while ensuring sufficient inventory for homeland defense by the Air National Guard.<sup>3</sup>

### Missile Defense in Context, and the Present BMD System

To understand why ABPI capability matters, we must explore why interception shortly after adversary missile launch is so vital, and could be decisive in a crisis. The present US missile defense program is now focused on intercepting and destroying missiles in the midcourse (long middle) and terminal (endgame descent) phases of flight. But US capability in these two segments are being challenged by adversary designs and technical gains. Potential adversary missiles can employ penetration aids—countermeasures, to complicate and delay detection, frustrate tracking and confuse lethal object identification, as these incoming missiles transit from midcourse into the early portion of terminal descent.<sup>4</sup>

Deeper into a missile’s terminal phase, deception measures may limit detection and tracking activities as the missile reenters the atmosphere and descends toward its target. It is much more operationally advantageous to sidestep an adversary’s potential midcourse penetration aids

to instead engage ballistic missiles in boost phase, where they are lower, slower, and operating without the aid of deception measures. This paper’s analysis outlines a well-reasoned approach to the attributes of an effective ABPI capability, and a concept of operations that shows how enemy missiles could be shot down within a short but manageable time window—when a ballistic missile is boosting.<sup>5</sup>

To understand the layers of the existing US missile defense enterprise, see Figure 1, which places the major pieces of the ballistic missile defense system relative to each other, correlated to the boost phase (green block), midcourse phase (yellow block), and terminal phase (salmon block). In addition to these capabilities, the Missile Defense Agency (MDA) manages experimental and contributing sensors that perform missile launch detection, tracking, and discrimination to enable effective response. Connecting these pieces is an enterprise-wide command and control system which coordinates and synchronizes the globally distributed missile defense enterprise across combatant commands and major leadership nodes such as the National Military Command Center. The software in this system undergoes periodic revision to increase its reach, improve network stability, and bolster its defenses from cyberattack.

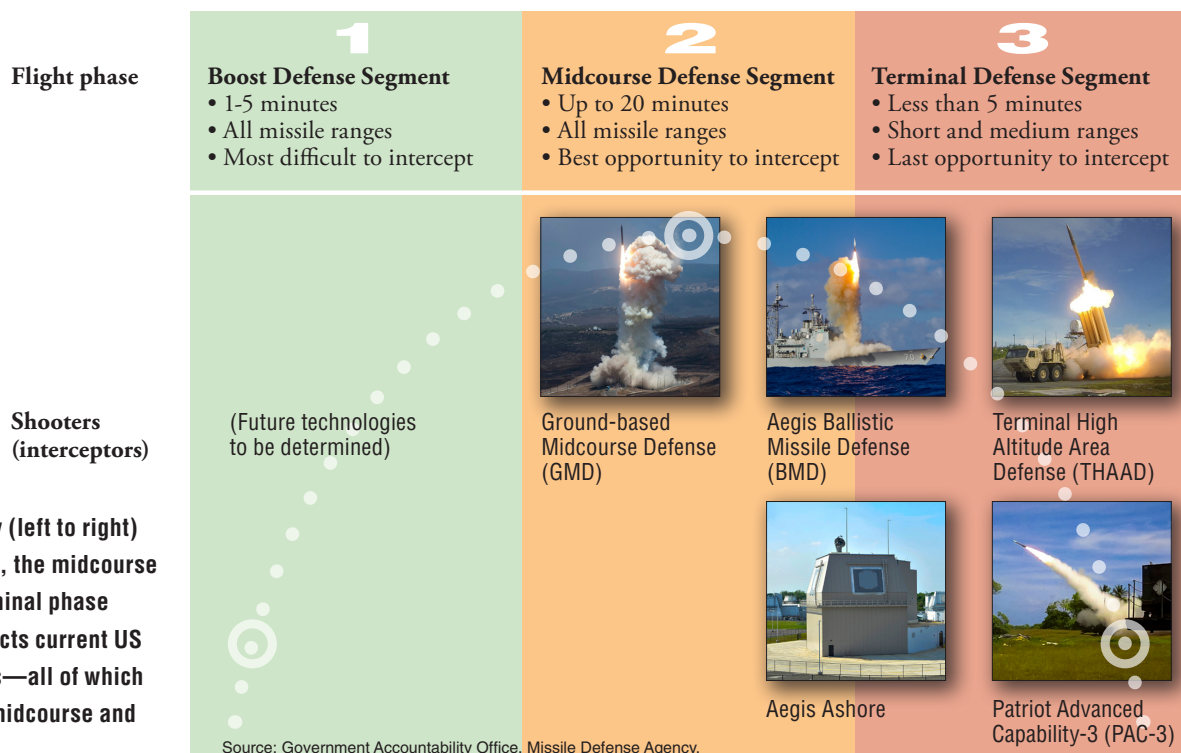


Figure 1: Broken down by (left to right) the boost phase segment, the midcourse phase segment, and terminal phase segment, this figure depicts current US kinetic intercept systems—all of which are concentrated in the midcourse and terminal phases.

Source: Government Accountability Office, Missile Defense Agency.

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Aside from developing a robust and capable missile defense system over the years, the deeper challenge lies not in locating achievable or even affordable solutions to boost phase engineering problems, but rather in changing today's ballistic missile defense thinking that is in many ways a "follower strategy." In this dynamic, a competitor begins an action or reaction loop by producing a cruise or ballistic missile system. In its missile defense apparatus, the US chases those developments by assessing and evolving its varied missile defense systems at different rates, to differing US armed service specifications. This cycle then becomes a competition to ensure US missile defenses remain viable in the face of adversary innovations.

The very presence of US defenses creates the motivation for competitor or adversary missile innovation, and stressing attack tactics to ensure their offensive missile systems remain relevant and reliable.<sup>6</sup> US defense and policy leaders must

recognize that the past 30 plus years of ballistic missile proliferation across the globe is the byproduct of long term competing strategies that successfully impose substantial economic costs on America.

Because adversaries and competitors can do this, it is more productive and ultimately less costly for them to threaten the US and its allies with ballistic missile systems, contrasted with the cost burden borne by the US to field and continuously innovate its ballistic missile defense capacity. An effective ABPI missile defense solution could help begin to change this dynamic over the long term.

**Boost Phase Missile Defense Shoot-Down Challenges: Reviewing the Critiques**

Though the current US missile defense architecture is heavily focused on intercepting missiles in midcourse and terminal defense, there is ample analysis that shows an ABPI solution deserves consideration. "Several operational limitations make the aerial boost phase intercept [ABPI] less than ideal for missile defense, although none are so constraining as to eliminate this boost-

phase defense option," writes research scientist and missile defense analyst Dean Wilkening.<sup>7</sup>

Earlier analysis of boost phase intercept concluded that as a mission it faces five primary challenges:<sup>8</sup>

- Boost phase engagement is problematic against large inland states
- Access to sovereign airspace may be required
- Air defenses may threaten US boost phase delivery aircraft
- Sustaining tactical aircraft interception orbits is costly
- Short engagement notice thwarts high-level decision-making processes

This section will briefly address each of these critiques.

**Against large inland states, boost phase defenses are problematic:** Numerous studies make different assumptions about the size and gross weight of candidate interceptor missiles shot from manned and unmanned aircraft at ballistic missiles. Nearly all serious analyses of aerial boost phase engagements support an interceptor launched from manned or unmanned aircraft from at least 30,000 feet (preferably 45,000 or more feet), with the highest possible shooter aircraft velocity.<sup>9</sup> While analysis diverges somewhat on the granular details of interceptor performance assumptions (and the estimated size of a shoot down performance ring), depictions are useful as an aid for illustrating engagement possibilities of a given ballistic missile interceptor.

Analysts Paul Zarchan and Wilkening calculated notional interceptor engagement rings predicated on a shot fired at a climbing North Korean ballistic missile at a firing range of 350 km (about 218 miles).<sup>10</sup> Interestingly, the assumptions used by Zarchan and Wilkening resemble the observed performance of North Korea's longest-range missile to date, the HS-15. Against a target like the HS-15 launched from the Korean Peninsula, US aircraft have interceptor launch capability overhead Russian or Chinese territory, and a second orbit over the international waters of the adjacent Sea of Japan. In this scenario, access to Sea of Japan ABPI launch orbits is assured.





**Figure 2:** This figure depicts the patrol and launch orbits of a 350-kg (770-lb) multi-stage airborne boost phase interceptor with a 3km/second divert performance capability against known ballistic missile designs (divert performance refers to the energy margin available to an interceptor to remove internal guidance and targeting aim error). The notional launch site of an Iranian missile is depicted by the red missile, with an azimuth fan aimed at targets in Europe.

Against a notional Iranian solid propellant missile motor design, interceptor “fly out”—or the effective aerodynamic range of an airborne boost phase interceptor—may shrink. More importantly, of the three engagement zones depicted in Figure 2, only two are orbits not directly overhead sovereign Iranian territory. In this scenario, to ensure US leaders have an ABPI option, US interceptor aircraft would have to be tailored combinations of fifth generation aircraft such as the F-35 and remotely piloted aircraft (RPA) systems such as modified US Air Force RQ-4s and US Navy MQ-4s, or other potentially survivable high-altitude platforms. In the past, the need to use these aircraft has been conflated with the notion that the use of such platforms in creative combinations with other capabilities is not executable. However, fifth generation aircraft are ideally suited for use in contested and challenging combat environments. The pairing of fifth generation aircraft with other assets is not a conceptual breakdown or fatal flaw with the premise of the ABPI mission. Instead, the fault lies in undue restriction imposed by outdated thinking.

**Access to sovereign airspace may be required:** This paper does not take a position regarding the international law implications of operating within the sovereign airspace of an aggressor nation before the start of hostilities.

Those are legal and policy decisions for the executive branch to debate and decide on. In the event of a war breaking out, sovereign airspace access becomes a moot point to the US, as it would clearly be engaged in hostilities. In other scenarios, there is more leeway and judgment based on the scenario to consider. In the event of a crisis, interceptor aircraft could penetrate airspace for brief periods as a show of force, or orbit close enough to be observed by an adversary intent on ratcheting up tensions by “saber rattling.” These options, and other similar responses, demonstrate credible capability and the will to use it on the part of the United States.

**Air defenses may threaten US boost phase delivery aircraft:** The most capable low observable, fifth generation aircraft should spend no more time within surface to air missile engagement envelopes than is appropriate. The challenge working the ABPI problem is that one must consider the actual capabilities of a belligerent nation’s air defenses as well as the operational performance of US fifth generation aircraft. Past analyses critical of ABPI have usually concluded that modern air defenses are no-go zones for all aircraft, but this does not reflect current US airpower capabilities, as modern fifth generation assets are designed to penetrate these environments.

**Figure 3: The green rectangle in this figure depicts the approximate launch envelope of a 700-kg (1,500-lb) two-stage airborne boost phase interceptor targeting a multi-stage liquid propelled ICBM with a 10,000-mile range. This green launch zone is outside of the territorial overflight of the “adversary country,” which in this case is represented by Florida (excluding the panhandle) and is outside all but the most advanced surface to air missile ranges. The single small red square in the bottom right corner represents the only area in the space where a boost phase interceptor could not fully satisfy all intercept criteria.**



While evaluating the operational geography of potential conflict regions such as Iran or North Korea is instructive, the problem is that as analysis, it can distort a layman's understanding of an interceptor engagement envelope. Figure 3 is an illustration that establishes the approximate missile performance area of a notional two-stage 700-kg (1,500-lb) airborne boost phase interceptor targeting a boosting liquid-propelled ballistic missile. This figure, however, takes the familiar geography of Florida, the Gulf of Mexico, and adjacent US states to illustrate how this notional interceptor's performance becomes more concrete and easier to reference. The green rectangle depicts a large area where an airborne boost phase intercept shot (using the two-stage interceptor design referenced above) would be feasible under the following circumstances: a required interceptor kill vehicle divert velocity of less than two km a second, the need for a kill vehicle that strikes the target ballistic missile before its motor burns out, and the necessity for an intercept that occurs at an exo-atmospheric altitude of 60 kilometers (or 200,000 feet). The minimum approach distance of approximately 120 miles from the western coast of the hostile state, represented by Florida in the diagram, is due to a generalized surface to air missile threat, and a 12-mile “no overflight” minimum approach distance from Alabama and Mississippi—in this scenario, these US states are

notional “allies.” The surface area of the green rectangle is approximately 84,000 square miles, and when the minimum approach distances above are applied, the permissible interceptor sub-area decreases to around 63,000 square miles. Despite this restriction, the single red square shown in the bottom right of the figure is still the lone engagement exception area where the theoretical interceptor cannot fully satisfy all three of the criteria listed above. This scenario shows that at certain airborne boost phase interceptor weight thresholds, successful engagement of an enemy missile is quite feasible as long as the launching aircraft remains clear of air defenses.<sup>11</sup>

**Sustaining boost phase interception orbits is costly:** The cost of interception orbits is a discussion both about real dollar and opportunity costs of aircraft force structure tied up in the ABPI mission. Fixed and variable cost estimation is outside the purpose of this paper. However, notional force requirements are worthy of mention. The sense of previous research on this topic tends to conclude that 24-hour on-station presence models of manned aircraft in multiple adjacent orbits waiting indefinitely to engage a ballistic missile launch are the likely deployment scenario for ABPI intercepts. However, that scenario is not a realistic depiction of how tactical airpower is postured and employed. The combined forces air component commander (CFACC), the senior airman in a combat theater, will tailor ABPI shooter aircraft coverage to those periods linked to appropriate intelligence and warning indications. In other words, remote piloted and manned aircraft systems would be airborne when it is appropriate and advantageous. Before a conflict may occur, aerial presence of ballistic missile boost phase interceptor aircraft is best thought of as a flexible deterrence option. For example, shows of force, presence, capability demonstrations, and ramped up operational tempo for deployed aircraft are all means by which the US can signal in a brewing crisis, to name just a few options.

Of note in these scenarios is that aircraft that function as sensor and shooter do not have to be full-time manned platforms, but must at least be capable of limited orbit times. There are other

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aerial systems such as high-altitude and specialized remote piloted aircraft with the ability to remain on station for more than 30 hours in some mission taskings. There are already testing and research efforts underway to utilize RPA in missile defense scenarios. As part of a development program, MDA has already tested modified MQ-9 Reapers with a multi-spectral targeting system to track ballistic missiles after launch from the air. The agency has also awarded contracts to develop preliminary designs for an RPA-based multi-kilowatt laser to demonstrate beam stabilization technology, as part of a program that includes developing a tracking laser, a defensive laser, and a beam-control system that could be mounted on RPA that fly at high altitudes as part of a boost phase defense concept. Because aerial based radars and lasers have greater

reach and fidelity in the air than at sea or on land, RPA sensors could be vital to any future boost phase missile defense concept of operations.<sup>12</sup>

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In this kind of high-end strike, enemy mobile missile launchers that attempt to move out and fire present close-in rising missile launch signatures that become targets for ABPI shooters.

In another scenario, ABPI shooters might establish their own aerial patrol orbits, offset from the ground tracks of the aerial attackers, to obtain a clear avenue from which to shoot down ballistic missiles launched before, during, and after strikes. In this operation, when shooting at rising ballistic missiles, other striking aircraft or their standoff weapons will perform a rapid reassignment to destroy exposed missile transporters and launchers.

Against this backdrop, ABPI interceptors will come to be associated with US and allied air dominance aircraft, owing to their speed, agility, and survivability. That puts the ABPI weapons in close proximity to an opponent's boosting ballistic missiles. Exploiting this operational closeness creates the opportunities to quickly suppress an enemy's missile raids, which would notionally be designed to overwhelm US missile defenses—especially in “use or lose” situations where an adversary regime is launching missile raids due to a sense of impending defeat or imminent destruction of their ballistic missile forces, or both.

**Short engagement notice thwarts high-level decision-making processes:** Crews from all three US armed services with fixed-wing combat aircraft—primarily the US Air Force, but also the US Marine Corps and US Navy—are intimately familiar with warfighting rules of engagement, the guidelines that govern armed response, and the use of force. Shooting down offensive ballistic missiles is no different than shooting down enemy aircraft. Rules can and do provide effective guidance to shooters, whether in fighter aircraft or at some distance from the battlespace, as would be the case with aircrews operating unmanned ABPI aircraft. These rules of engagement provide the method to pre-delegate interception authority to ABPI shooters. Moreover, an ascending ballistic missile from hostile territory easily conforms to “guilt by association” if identified readily, and becomes instantly eligible for ABPI destruction.

### **The Interceptor Weapon: The Core ABPI Capability**

The weapon that aircraft would carry to shoot down enemy ballistic missiles will be a product of design tradeoffs—most visibly, size and weight. Obtaining credible aerial interception capability sooner rather than later, and at manageable development risk levels, involves using a weapon with proven size and weight for the task. Since this weapon will be launched from manned and unmanned aircraft, it must be compatible with existing weapon carriage constraints of currently fielded aircraft. The next attribute is that from a size and shape perspective, it ought to resemble air-to-air missiles carried on US fighters.



Figure 4 depicts two classes of interceptor weapons, an emergency capability dubbed “generation 1.0” (a radar-guided AIM-120 variant) and the “generation 2.0” objective interceptor weapon, a three-stage dual-mode seeker interceptor that conforms to the maximum weapon length (12 feet) and maximum internal carriage weight limits of the F-22 and all versions of the F-35.<sup>13</sup> A variant not depicted in the diagram, but still important for early capability, is the AIM-9 heat-seeking family of air-to-air missiles (for first generation engagements). This AIM-9 interceptor would be similar to the AIM-120, but with two main modifications: a firmware update—improved missile memory, to enable guiding and tracking more efficiently on boosting ballistic missiles; and the installation of a divert and attitude control system. The divert and attitude control system would be constructed using existing technology and insights learned from previous Missile Defense Agency testing efforts.<sup>14</sup> The first-generation weapon class takes the AIM-9 and AIM-120 missile, updates their flight performance algorithms, then uses cuing and tracking information derived from offboard sources and systems for a feedback loop to the shooter in the aircraft.<sup>15</sup> During ABPI operations, the pilot receives an in-range launch cue, prompting the release of the missile, and its flight along the interception path.

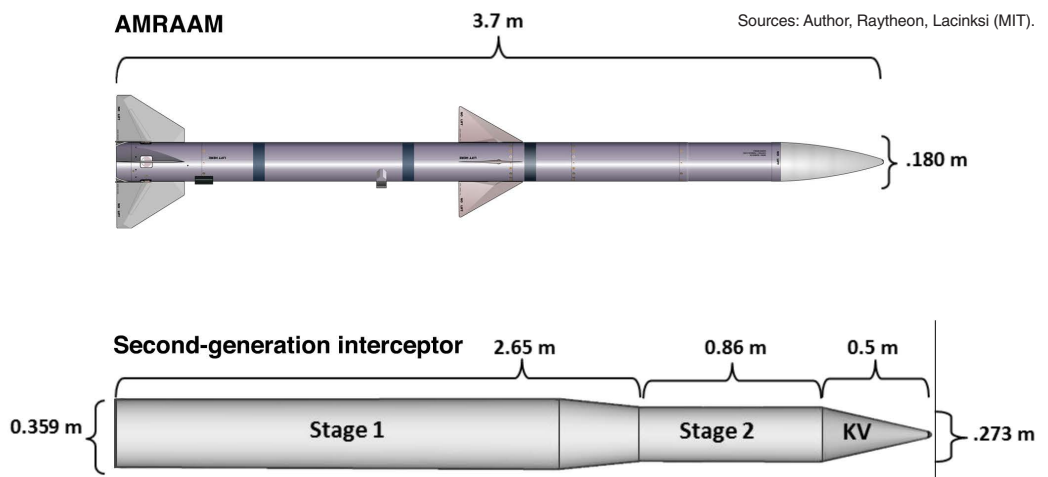
Though there are technical challenges, they are not daunting for a first-generation weapon development effort. Getting an AIM-9 and AIM-120 firmware upgrade fielded that can perform the ABPI mission could be accomplished in approximately 18-24 months after authorization.

The generation 1.0 weapon would intercept ballistic missile targets within the atmosphere and would not require the ability to maneuver above it. The second-generation weapon would be a new weapon development program, but much of its basic design and performance attributes are currently proven in other air-to-air weapons programs. The second-generation interceptor must also be a multi-stage weapon. See Figure 4 for an example of a two-stage design with a kill vehicle (KV) that detaches from the second stage booster at burnout. After coasting briefly, the KV’s kick motor ignites to remove aiming error while the ABPI weapon proceeds to the predicted impact point with the targeted ballistic missile.<sup>16</sup>

The guidance for a new build ABPI weapon is derived from the same systems that would cue the first-generation weapon, but with an important exception. The second generation ABPI weapon must have a dual-mode seeker.<sup>17</sup> The ability for a next-generation interceptor to track a climbing ballistic missile combined with an embedded artificial intelligence performance engine means that unlike previous designs this weapon could be sized for carriage onboard US military tactical aircraft.<sup>18</sup> This generation 2.0 ABPI weapon would use state-of-the-art high energy, high efficiency, solid propellant technology to wring the most energy possible from this interceptor’s stages.<sup>19</sup>

Unlike first generation interceptors, the generation 2.0 missile must be able to track and maneuver above the atmosphere. To maneuver above the atmosphere, this interceptor will require a specialized maneuvering system built into the missile.<sup>20</sup> The estimated development time of a

**Figure 4: The AIM-120 AMRAAM depicted in this figure (at top) is an approximate disposition of a generation 1.0 ABPI capability. The interceptor at bottom is a notional generation 2.0 multi-stage interceptor. The second-generation weapon is slightly longer than the AMRAAM variant in this depiction, but both would be around 144 inches in length. The mass of the second-generation interceptor would be greater than the AMRAAM.**





generation 2.0 weapon is approximately four years, and should be undertaken in parallel with the development of first generation interceptors.<sup>21</sup> Both the first and second generation weapons would use existing data link technologies, such as Link 16, and other high-speed systems associated with rapid intelligence, surveillance, and reconnaissance (ISR) data movement such as the DOD's global broadcast system (GBS).

Interestingly, the advanced infrared sensing capabilities of the F-35's distributed aperture system suggest potential for a separate in-atmosphere constellation of distributed aperture sensors added to other in-atmosphere platforms.<sup>22</sup> Were such a constellation to be fielded and netted together, it would add an agile new system in a construct capable of being a forward edge plug-in to the ballistic missile defense enterprise.

### The ABPI Concept of Operations

Another important distinction between generation 1.0 and 2.0 boost phase interceptor weapons is how rapidly the capability must be in the field to meet threats. The advances of the North Korean intercontinental ballistic missile program create a pressing need to shoot down these missiles close to their points of origin, should

they be launched against US or allied targets. ABPI is not intended to displace other elements of the US ballistic missile defense enterprise, because it fills a boost phase mission space unoccupied by any other capability. The aggregate effect of ABPI is that it adds to the US ballistic missile defense enterprise in ways that aid the existing structure and leverages technology that already exists to make US

territory, US forces overseas, and US allies and partners safer. But, how are ballistic missiles to be shot down? What follows is a conceptual outline of ABPI operations.

To cue a generation 1.0 interceptor weapon, aircrews will rely on existing systems that rapidly sense and position-fix missile launch smoke plumes and detect rising ballistic missiles—each with a substantial heat and radar signature (these sensors have a generally low false alarm rate).<sup>23</sup>

In ballistic missile launch scenarios, the US has the means to provide a low false-alarm rate typed missile launch location message 30 to 45 seconds after launch. If this time span can be held constant, aircrews can build tactics, technologies, and procedures from that time foundation. This is important because the aerial engagement window is brief, but manageable by experienced pilots and crews who are the US military's authorities when it comes to the dynamics of time-sensitive aerial engagement.<sup>24</sup>

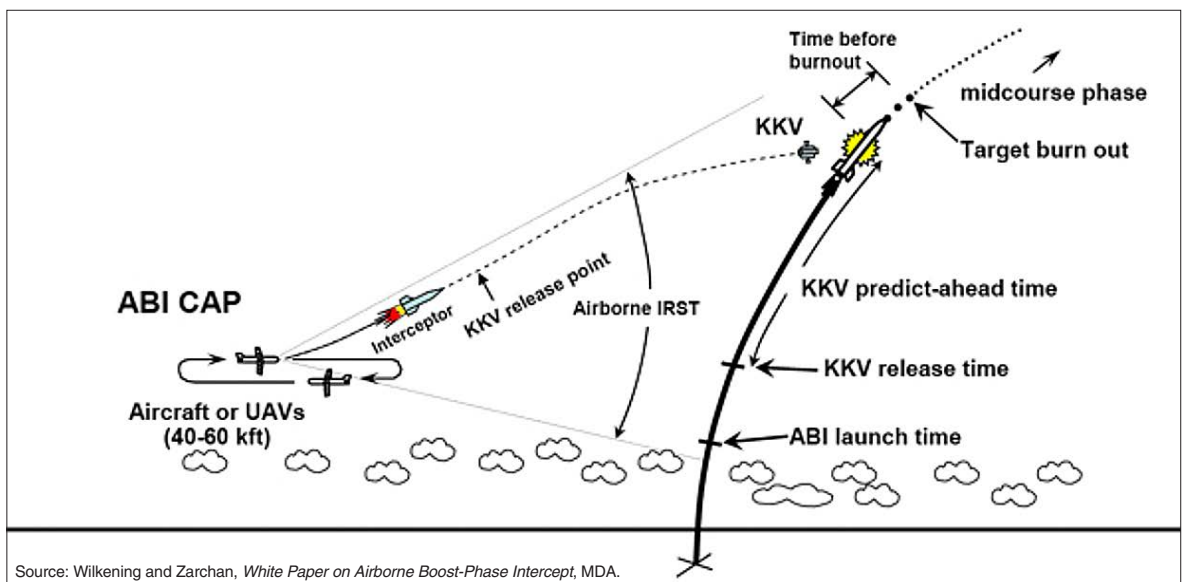
In contrast, if one is evaluating a "bolt from the blue" launch scenario—one of the most demanding defense situations, where a ballistic missile is launched with little to no warning—the US must rely on the GMD silo-based interceptors in Alaska and California. The GMD system's last successful test was FTG-15, conducted in May 2017, a test that lifted the overall GMD system's success rate.<sup>25</sup> But behind GMD, there are no other US missile defense systems protecting the continental United States. Forward-positioned defensive systems act independently and beneficially lower GMD's engagement burden.<sup>26</sup> In forward combat theaters, ABPI can also compliment the US Army's Terminal High Altitude Area Defense (THAAD) batteries and the US Navy's Aegis Combat System in the same way.

For a second-generation interceptor weapon, investments in more of America's missile sensing and detecting programs of record (and a maturation of those systems in the field) would deliver improved preparation and warning capability for ABPI operations. These improvements would aid missile launch accuracy. With better initial warning and cueing, the entire missile defense enterprise could be more effectively managed in real time, leading to added gains in engagement efficiency.

ABPI aircraft armed with generation 2.0 interceptors will be able to position farther back from likely ballistic missile launch points, due to the longer range and improved capabilities of a second-generation weapon. The F-35 would be a formidable asset to utilize in an ABPI scenario, armed with a second-generation interceptor weapon. Because the F-35 has a built-in distributed aperture system with the ability to see and track a rising ballistic missile, the mere presence of

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**Figure 5:** This figure is a simplified illustration of the ABPI concept of operations. The shooter orbits at high altitude. With missile launch location and missile type confirmed, the shooter turns to launch an interceptor weapon as the ballistic missile (at right) climbs after launch—culminating in a successful intercept.



Source: Wilkening and Zarchan, *White Paper on Airborne Boost-Phase Intercept*, MDA.

F-35s adds an element of redundancy and added accuracy to the missile sensing elements of the missile defense enterprise. Other tactical aircraft without a distributed aperture system could leverage externally mounted, improved infrared pods to locate a boosting ballistic missile.<sup>27</sup> With an established track of a rising enemy missile, a two-ship formation of F-35s would have sufficient resolution using their distributed aperture systems to locate and then point their aircraft at the proper threat missile, accelerate, and climb (to more than 45,000 feet, as supersonic launch speed is desired) into an optimal “shooter box”—the most desirable spot in the combat zone to launch an interceptor.<sup>28</sup> Senior MDA leadership has already taken notice of the inherent capabilities of the F-35 in the ballistic missile defense mission, and is working to integrate its capabilities into the missile defense enterprise. The F-35, said MDA’s Director, Air Force Lt Gen Samuel Greaves, “will be out there in numbers” wherever conflict breaks out in the future. “If you know anything about that platform... it’s got a magnificent suite on it and it’s a great platform for potentially launching boost phase defense capability against the threat,” he declared in a recent speech on the state of missile defense.<sup>29</sup>

While the F-35’s capabilities and potential are often discussed at length given its multi-service scope and superior air combat capabilities, other extant unmanned and remote piloted aircraft such as a modified MQ-4s or RQ-4s could also develop alongside manned fighter shooters to add ABPI mission flexibility. However, the ability to

conduct ABPI with the F-35 gives US combatant commanders incredible flexibility to conduct ABPI in heavily contested and defended airspace.

The intent of this basic concept of operations is that the US ballistic missile defense architecture works rapidly in the background to push refined missile tracking data, including missile identity, to an ABPI shooter aircraft as far in advance of interceptor release.<sup>30</sup> Getting ballistic missile tracking data to the pilot or operator at the first opportunity, then following with rapid updates, allows the shooter to maneuver in ways that optimize interceptor release conditions.<sup>31</sup> After the interceptor is fired from its host aircraft, representative elements of the ballistic missile defense architecture continuously push data updates to the weapon as it zooms toward the impact point.<sup>32</sup> The interceptor finally transitions to terminal homing as it nears the target—at the point where its internal sensors begin generating guidance commands to establish the weapon on an energy-conserving collision course with a climbing ballistic missile.

Figure 5 is a rendering of the major components of the ABPI concept. An “ABI CAP”—or airborne boost intercept combat air patrol—are tactical aircraft specifically positioned on air or ground alert. This presence could be manned or unmanned aircraft, or both acting together.<sup>33</sup> An airborne infrared search and track system (IRST), as depicted, would be carried in an external pod or integrated into the CAP aircraft. The F-35, however, would not require an external infrared search and track pod as it has a built-in distributed

aperture system—making it a prime candidate for integration into the missile defense enterprise and concepts of operation in the near term, according to senior DOD and MDA officials.<sup>34</sup> While this operational discussion has focused on intercepting boosting missiles in overseas combat theaters, it should be noted ABPI has an additional utility: homeland and continental defense of the United States. ABPI would use the same interceptor weapons, missile defense enterprise, data links, and fighter aircraft performing this mission overseas.

As two aerial boost phase experts pointed out in a 2011 essay, the dynamics of terminal engagements are notably different. In terminal phase, downward accelerating incoming missiles are clear of the decoys common to midcourse flight. In a missile's terminal phase, engagement time remaining is still the same precious asset it was in the boost phase.<sup>35</sup> Interceptors carried onboard aircraft, however, have a unique advantage in the aerial domain: they can be optimally positioned within minutes by supersonic aircraft that align their launch shots directly opposite an incoming ballistic missile's approach axis. This helps cancel out the intercept challenges imposed by a downward moving, rapidly accelerating ballistic missile, and improving the probability of a shoot down.<sup>36</sup>

Given that the Air National Guard performs the air sovereignty alert mission today over the continental US, equipping the ANG to perform the terminal defense interceptor mission involves controllable costs in areas such as academics, simulator training, familiarization sorties, aircraft software, and procuring a sufficient quantity of first or second-generation interceptor weapons. With this concept of operations valid in both forward theaters and in homeland defense, the US inherits a backstop to the GMD, a still-evolving system with an uneven record of test-range intercepts.

### **Making ABPI a Reality: The Next Steps** \_\_\_\_\_

To bring this concept into reality, the material side of ABPI will require a detailed system architecture plan that identifies what development functions and systems engineering gains are

required to develop first and second-generation interceptors. Using processes and methods such as the prototyping models of the Defense Advanced Research Projects Agency (DARPA), the DOD's Strategic Capabilities Office (SCO), and the Air Force's Rapid Capabilities Office (RCO), the first and second-generation interceptor weapon development effort should be a two-track, simultaneous program. Data collection and scientific analysis must also be improved and increased, to deepen what is known about threat ballistic missiles. These data collection tasks are needed to fill in performance gaps of threat missiles, and to reevaluate US early launch, detection, and tracking capabilities (which will help determine which of these elements require expansion). Better data collection and analysis will also build the pool of information needed to populate the artificial intelligence engine installed in each ABPI weapon, and the software patches for installation in fighter aircraft flight programs.

Viewing ABPI from a roles and missions perspective, the addition of this task to the existing US military missions of air supremacy and air superiority should be cause to manage ABPI not as an MDA program but as a DOD special project, with a multi-service program office or similar model. DOD-led development should be the preferred course of action for the ABPI effort, given previous resistance to moving the concept past desktop analysis and into demonstration and testing. It should be stressed that the technology needed to get a generation 1.0 interceptor weapon capability fielded currently exists. In addition, most (but not all) of the development needed for a second-generation interceptor involves integration of existing materials and technologies. These technologies could also become a force multiplier with US allies and partners in combined operations. Once the program is off and running, ABPI should be developed and marketed to US allies with highly capable air forces, such as Israel, Japan, South Korea, and several of the NATO countries.

By fast tracking this critical capability, this effort would get needed ABPI into the hands of airmen and warfighters at a relevant speed, and put a more capable weapon on the path to successful development and deployment in just four years after starting the effort.

**Interceptors carried onboard aircraft, however, have a unique advantage in the aerial domain: they can be optimally positioned within minutes by supersonic aircraft that align their launch shots directly opposite an incoming ballistic missile's approach axis.**

## Concluding Thoughts on ABPI

A successful ABPI capability would realize a previously unmet airpower mission to shoot down ballistic missiles. This use of airpower is well within the doctrine of US Air Force, US Navy, and US Marine Corps airpower that protects forward military forces, ships, bases, and logistical hubs, and could have transformative operational effects over time.

History is also instructive with regard to this mission. On the night of February 25, 1991, a single Iraqi Scud missile descended from the sky on a Pennsylvania National Guard barracks in Dhahran, Saudi Arabia. In follow up analysis of this strike, it became clear that the Patriot surface-to-air missiles fired at the Scud failed to intercept it before impact. Upon impact, the Iraqi Scud killed 28 soldiers and injured over 100. In comparison, Iraqi MiGs in Operation Desert Storm were responsible for none of the 149 combat deaths. Since the end of the Gulf War, potential adversaries such as China, Russia, Iran, and other nations have invested and built up ballistic missile capabilities of varying size and scope. The lesson from the Gulf War is clear: ballistic missiles are a relatively affordable means to threaten US bases, forces, and even the continental United States—and the addition of nuclear and chemical payloads multiply those risks to both the US military as well as civilian populations.

Destroying enemy aircraft is a core US Air Force mission. However, in warfare, the enemy always gets a vote. The contemporary evidence

indicates that a modern adversary's most destructive presentation of airpower is not legions of MiGs meeting in vast formations over a contested battlespace. That vision of aerial warfare may have passed with the end of the Vietnam War. Instead, potential adversaries will field airpower capabilities they believe will lead them to victory or at least hold US strengths at bay: one-way, single use airpower systems such as ballistic missiles.

It is past time for leaders, policy makers, airmen, and all US military aviation servicemembers to widen the aperture to perceived threats that already fall within their doctrinal air supremacy and air superiority missions. Missile defense is a joint force operation and collective mission across the US military services, not just the domain of the US Navy or US Army. Potential adversaries with ballistic missile forces intend to use them against the US and its allies in combat, not just the US Navy or US Army. In the interest of the best defense against the ballistic missile threat—elements of which could take on an offensive look, ABPI is a holistic, DOD-wide tactical airpower response to Mattis' statement on the future of US military advantage.

The challenge is to innovate now—faster than the speed of relevance, and before the US is surpassed by an emergent North Korean missile threat whose technologies and offensive approach will proliferate to other potential adversaries. In the absence of a potent ABPI defense, these adversaries could then leverage this capability against the US and its interests in the future. ★

**Figure 6: An F-15E is shown here with a notional loadout of generation 1.0 airborne boost phase interceptor weapons. First generation interceptors could be quickly fielded on many currently operational combat aircraft in the US military's inventory.**



Source: Boeing.



## Endnotes

- 1 Michael Elleman, "The New Hwason-15 ICBM: A Significant Improvement That May Be Ready As Early As 2018," *38 North*, November 30, 2017, <https://www.38north.org/2017/11/melleman113017/> (all links accessed July 2018).
- 2 Cheryl Pellerin, "Mattis: DoD Lines of Effort Include Building A More Lethal Force," DOD News, September 20, 2017, <https://www.defense.gov/News/Article/Article/1318291/mattis-dod-lines-of-effort-include-building-a-more-lethal-force/>.
- 3 Authors' note: The figure of 300-500 aerial interceptors is an informal estimate based on 50-100 being reserved for US homeland protection as a backstop terminal intercept capability, serving as an adjunct to the Alaska-based Ground-based Midcourse Defense system (GMD). The remaining 400-450 aerial interceptors may best boost US deterrence by being forward based in South Korea, Japan, and other US sites in US Pacific Command (PACOM). Interceptors could also be based in US Central Command (CENTCOM) and US European Command (EUCOM) to add to existing missile defense systems or to enhance regional deterrence. For further study, it is likely wargaming would be required to refine both the total number of required aerial interceptors and basing schemes.
- 4 Dean Wilkening and Paul Zarchan, *White Paper on Airborne Boost-Phase Intercept*, Missile Defense Agency Report No. 10-MDA-5210 (Washington, D.C.: MDA, April 29, 2010), 5.
- 5 Authors' note: The boost phase engagement window size varies based on whether the missile is fueled by solid or liquid propellant, as well as its intended target distance. The average boost phase intercept window time, based on past precedent and testing, is 90 seconds to four minutes.
- 6 Reuben Steff and Nicholas Khoo, "Hard Balancing in The Age of American Unipolarity: The Russian Response to US Ballistic Missile Defense During the Bush Administration," *Journal of Strategic Studies*, Vol. 37 No. 2, (May 2014): 222-258.
- 7 Dean Wilkening, "Airborne Boost-Phase Ballistic Missile Defense," *Science and Global Security*, Vol. 12 (2004): 1-67.
- 8 Ibid.
- 9 James Kiessling, Office of the Assistant Secretary of Defense for Research & Engineering, author interview, February 8, 2018.
- 10 Authors' note: This assumes a 750 kilogram two-stage interceptor that achieves a velocity at the time its final stage burns out at a peak velocity of approximately 4 kilometers a second, from launch ranges of 250-350 kilometers.
- 11 Authors' note: This figure is computed by the east-west length of the depicted engagement zone (approximately 350 miles) and by its north-south distance of approximately 175 miles; a surface area of over 61,000 square miles.
- 12 Authors' note: The MDA is actively working with firms such as General Atomics Aeronautical Systems and Raytheon to improve RPA capabilities that can support boost phase missile defense activities.
- 13 Authors' note: For currently fielded fifth generation fighters, there are maximum length, diameter, and gross weight restrictions on the internal carriage of weapons.
- 14 Authors' note: The divert and attitude control system is known in military parlance as a DACS.
- 15 James Kiessling, *A Critique of Assumptions Within: Report of The American Physical Society Study Group on Boost Phase Intercept Systems for National Missile Defense: Scientific and Technical Issues*, Missile Defense Agency Report No. 10-MDA-5536, unclassified, distribution approved for release (Washington, D.C.: MDA, June 14, 2010).
- 16 Authors' note: Using commercially available on-the-shelf propellants, the threshold kill vehicle design could offer performance at a specific impulse propulsive force for 280-290 seconds for the first stage, and approximately 315 seconds on a liquid kill vehicle stage.
- 17 Kiessling, author interview, February 8, 2018.
- 18 Ibid.
- 19 Authors' note: The outline of the generation 2.0 interceptor put forward here would draw down the kill vehicle mass atop a flexible final boost stage. This approach depends on the artificial intelligence engine's algorithms to best drive threat guidance, based on sensed external data feeds. Dropping kill vehicle divert velocity from 2 kilometers a second, to 1.5 kilometers a second, to 500 meters a second decreases interceptor gross weight, reduces overall size, lowers technical risk, and would lower unit cost.
- 20 Authors' note: This specialized maneuvering system is the DACS, mentioned previously.
- 21 Kiessling, personal communication with the author, February 5, 2018.
- 22 Authors' note: The AN/AAQ-37 sensor system equipped on the F-35 may be mountable on other aerial platforms such as the MQ-9 Reaper or other staring sensor systems, such as ultra-high-altitude balloons (operating above 100,00 feet).
- 23 Kiessling, personal communication with the author, February 9, 2018.
- 24 Authors' note: The window may be approximately 90 seconds when dealing with the launch of a mid-range ballistic missile. For high performance, solid fuel intercontinental ballistic missiles the engagement window begins around 30 to 45 seconds after launch and ends approximately three to four and a half minutes post launch.
- 25 Sydney Freedberg, "GMD Missile Defense Hits ICBM Target, Finally," *Breaking Defense*, May 30, 2017, [breakingdefense.com/2017/05/missile-defense-hits-icbm-target-success-rate-now-50](http://breakingdefense.com/2017/05/missile-defense-hits-icbm-target-success-rate-now-50).
- 26 Authors' note: With 44 silo-based missiles on status, the United States might have zero remaining continental US midcourse interceptors with a missile raid or raid totaling 22 missiles, assuming a GMD shot doctrine of "shoot—look—shoot" is in place.
- 27 Authors' note: Externally mounted pods, such as an improved Litening targeting pods, have sensing range limitations. If the pods are netted within defensive systems network, they could deliver additive data.
- 28 Authors' note: A two-ship interceptor employment is referred to as "stereo tracking," a concept that has already been effectively demonstrated.
- 29 Lt Gen Samuel Greaves, USAF, director, Missile Defense Agency, "Missile Defense in a Dangerous World: A Report" (speech delivered as part of The Mitchell Institute's Nuclear Deterrent and Missile Defense Breakfast Series, The Capitol Hill Club, Washington, DC, June 26, 2018).

30 Paul Zarchan, personal communication, January 29, 2018.

31 Mike Corbett, personal communication, January 18, 2018.

32 Paul Zarchan, personal communication, January 30, 2018. Authors' note: Probable Impact Point (PIP) is the place in three-dimensional space where the interceptor is planning to collide with the ascending ballistic missile.

33 Tim Wright, "Could Drones Shoot Down ICBMs?" *Air and Space Magazine*, June 13, 2017, <https://www.airspacemag.com/daily-planet/could-drones-shoot-down-icbms-180963660/>; Jen Judson, "MDA Awards Contracts for a Drone-Based Laser Design," *Defense News*, December 11, 2017, <https://www.defensenews.com/land/2017/12/11/mda-awards-three-contracts-to-design-uav-based-laser/>.

34 Sydney Freedberg, "F-35 Ready for Missile Defense By 2025: MDA Chief," *Breaking Defense*, April 11, 2018, <https://breakingdefense.com/2018/04/f-35-ready-for-missile-defense-by-2025-mds-chief/>.

35 Mike Corbett, personal communication, January 19, 2018. Authors' note: The time remaining during the terminal phase of any ballistic missile reentering the atmosphere requires that ABPI shooters performing sovereign airborne missile defense be airborne and in their pre-designated CAPs. This aerial posture is a mission similar to defensive counter air (DCA).

36 Mike Corbett and Paul Zarchan, "The United States Should Develop A Missile Defense That Builds Confidence," *Air & Space Power Journal*, (Fall 2011): 74-90.

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