The Anti-Satellite Capability of the Phased Adaptive Approach Missile Defense System

— BY LAURA GREGO

In early 2008, President Bush tasked U.S. Strategic Command with Operation Burnt Frost: "mitigating" the threat posed by a non-responsive intelligence satellite that was soon to re-enter the Earth's atmosphere. USA-193 had been launched into orbit just over a year earlier, and its fate was sealed after the National Reconnaissance Office was unable to establish control over the satellite after launch. While the imminent re-entry of a satellite was not in itself at all remarkable—70 tons of space debris and scores of large objects drop out of orbit each year without any casualty and without any operations mounted in response—administration officials expressed concern that leftover hydrazine fuel aboard the satellite might survive re-entry and hurt someone on the ground.

On February 14, 2008, General James Cartwright announced the United States would destroy the satellite using the Aegis sea-based missile defense system. After a few days of waiting out rough seas, on February 20, the U.S. Navy Ticonderoga-class cruiser Lake Erie launched an SM-3 missile which intercepted the USA-193 satellite.

While framed as a public safety measure, some observers expressed skepticism that this risk was the real or entire motivation for the exercise. The interception, at an altitude of 240 kilometers (km), vividly demonstrated the ASAT capability of the U.S. Aegis sea-based missile defense system. The intercept required only modification of the system software,[1] and could have been done from any of the 5 cruisers or 16 destroyers equipped with the Aegis system at the time (two destroyers were slated to be backups to the USS Lake Erie).

The context is important. This was the first time the United States had deliberately destroyed a satellite since 1985; Russia hadn't done so since 1982.[2] This unofficial moratorium had been recently broken by China in 2007, when it destroyed its own aging weather satellite at 800 km altitude. The Bush administration had withdrawn from the Anti-Ballistic Missile Treaty in 2002 and expressed interest in a range of new military uses for space, including space-based weapons and anti-satellite weapons. Just a week before Operation Burnt Frost was carried out, China and Russia had circulated to the Conference on Disarmament a draft treaty that would ban putting weapons in space and using force against satellites.[3] The United States responded with little interest, saying that there was no need for arms control in space.[4]

Operation Burnt Frost, in turn, is important context for the announcement eighteen months later of the Obama administration's new plans for European missile defense, the Phased Adaptive Approach (PAA).

This new PAA plan replaced the George W. Bush administrations' plan that aimed to protect European allies from missile threats in the Middle East using powerful ground-based interceptors in Poland and a radar in the Czech Republic. PAA would rely on and substantially expand and improve the Aegis missile defense system used in Operation Burnt Frost and demonstrated to have anti-satellite capability.

The Phased Adaptive Approach to European Missile Defense

The PAA system's much smaller SM-3 interceptors are to be based primarily at sea on Aegis ships converted to the purpose as well as some land-based "Aegis ashore" sites. It is meant to be flexible and address emerging ballistic missile threats from the Middle East over the coming decade. It will be improved incrementally, in four phases. The current generation of the SM-3 missiles, Block 1, will eventually be augmented with longer-range, more sophisticated missiles. More ships would be outfitted with new missiles and new and improved sensors added. Land-based sites would be added starting in 2015.

Currently, only the Block IA variant of the SM-3 missile is deployed. The Block IB interceptors, currently under testing and development, are based on the same 3-stage booster missile as the Block IA missile, but the Block IB kill vehicle will have sensors that can image the target at two wavelengths and increased capability to maneuver ("divert capability"). Both Block I interceptors have a reported burnout velocity of 3.0-3.5 km/s. The Block IIA will have longer range and a seeker with better discrimination and more divert capability. The Block IIA interceptors are expected to burnout at a velocity 45-50percent faster than the Block I missiles, so in the range of 4.5 to 5.5 km/s.[5] The Block IIB interceptor is still in the conceptual stage, but is meant to engage intercontinental-range ballistic missiles and to have yet higher propulsion. It may be land-based only.

The plan is to make all versions of the SM-3 missile able to be launched from the launch tubes on the Aegis ships.

Also important is the development of more sensors and the capability of the Aegis ships and sites to perform "launch on remote," the ability to launch on the cue from a sensor not on the ship. This will allow the interceptors to launch from a greater range. This capability was first introduced to the Aegis system after Operation Burnt Frost and will now become standard.

Missile Defenses as ASAT Weapons

While Operation Burnt Frost was the first time the United States used a missile defense system to destroy an orbiting satellite, the United States has for years had some intrinsic ASAT capability in its existing missile defense programs. Both the Aegis BMD and Terminal High Altitude Area Defense (THAAD) missile defense systems were considered during the preparation of Operation Burnt Frost,[7] although THAAD, like the SM-3 Block 1 systems, would be useful only against the lowest altitude satellites.

The U.S. Ground Based Midcourse (GMD) missile defense system with a total of 30 deployed interceptors in Alaska and California[8] and the recently shuttered Airborne Laser, also have intrinsic anti-satellite capability.[9] The GMD interceptors could reach nearly any satellite in low earth orbit (LEO).

The SM-3 is designed to intercept warheads in the midcourse phase of flight, when they are above the atmosphere. The kill vehicle carries its own fuel for maneuvering as well as an infrared sensor. The sensor is intended to guide the interceptor toward an object and allow it to home in on and destroy the target by direct impact, or "kinetic kill."

Because midcourse missile defense systems are intended to destroy ballistic missile warheads, which travel at speeds and altitudes comparable to those of satellites, such defense systems also have ASAT capabilities. In fact, while the technologies being developed for long-range missile defenses might not prove very effective against ballistic missiles—for example, because of countermeasure problems inherent in midcourse missile defense—they could be far more effective against satellites.

In many ways, attacking satellites is an easier task than defending against ballistic missiles. Satellites travel in repeated, predictable orbits that ground facilities can accurately determine by tracking them. An attacker would have time to plan an attack against a satellite, could choose the time of the attack in advance, and would be able to take as many shots as necessary to destroy it whereas advance notice of a ballistic missile attack is unlikely. In addition, an interceptor attacking a satellite would not have to contend with the same countermeasure[10] problems that a midcourse missile defense system would face.

Table 1. Summary of important characteristics of the Phased Adaptive Approach system[6]

Phase/year	Number, SM-3 variant	Burnout velocity	Platforms
1/2011	111 Block IA/IB	3 -3.5 km/s	23 Aegis ships
2/2015	263 Block IA/IB	3 – 3.5 km/s 4.5 km/s	38 Aegis ships 1 site in Romania
3/2018	486 Block IA/IB 14 Block IIA TBD Block IIB	3 - 3.5 km/s 4.5- 5.5 km/s ---	43 Aegis ships 1 site in Romania 1 site in Poland
4/2020	486 Block IA/IB 29 Block IIA TBD Block IIB	3 – 3.5 km/s 4.5 – 5.5 km/s ---	43 Aegis ships 1 site in Romania 1 site in Poland

Table 2. Maximum altitude reachable by SM-3 variants.

SM-3 variant	Burnout velocity (km/s)	Maximum reachable altitude (km)
Block IA	3.0	600
Block IIA (lower range)	4.5	1450
Block IIA (upper range)	5.5	2350

Countermeasures can severely limit the ability of a midcourse missile defense to defend against ballistic missiles: warheads and lightweight decoys move on the same trajectories in the vacuum of space, and the interceptor's onboard sensor or ground-based radars would be unable to distinguish these decoys from the warhead. An attacker can release numerous decoys along with the warhead in order to confuse the missile defenses or exhaust them by forcing them to intercept all the decoys along with the warheads.

Operation Burnt Frost showed that SM-3 interceptors can successfully intercept satellites if they can be reached. LEO satellites are generally in highly inclined or nearly polar orbits, and their orbits will take them over any given region on earth (with latitude below the inclination angle) twice a day. Since an attacker could choose the timing and geometry, the attack can be mounted when the satellite is overhead and the missile defense interceptor may therefore use its velocity to reach the highest altitude possible rather than to reach out laterally. A rough estimation of the maximum altitude an interceptor can reach may be calculated by setting the kinetic energy of the interceptor at burnout (when the missile ceases powered flight) to the potential energy at the given altitude.

The current Aegis interceptors SM-3 IA/IB can reach only the relatively few satellites in orbits with perigees at or below 600 km altitude. However, even using a conservative estimate of the burnout speed (4.5 km/s), SM-3 Block IIA interceptors would be able to reach the vast majority of LEO satellites (see Figure 2).[11] Interceptors with burnout speeds at the high range of estimates for the SM-3 IIA (5.5 km/s) would be able to reach any satellite in LEO, as would GMD interceptors.

PAA as a Strategic ASAT Weapons System

While the United States has long had ASAT capability in its missile defense systems, the PAA system as conceived is ASAT capability on a much different scale. The enormous potential size of the capability is new. While the projected inventory of Block II SM-3 interceptors is modest—there are 29 Block IIA interceptors and an undefined number

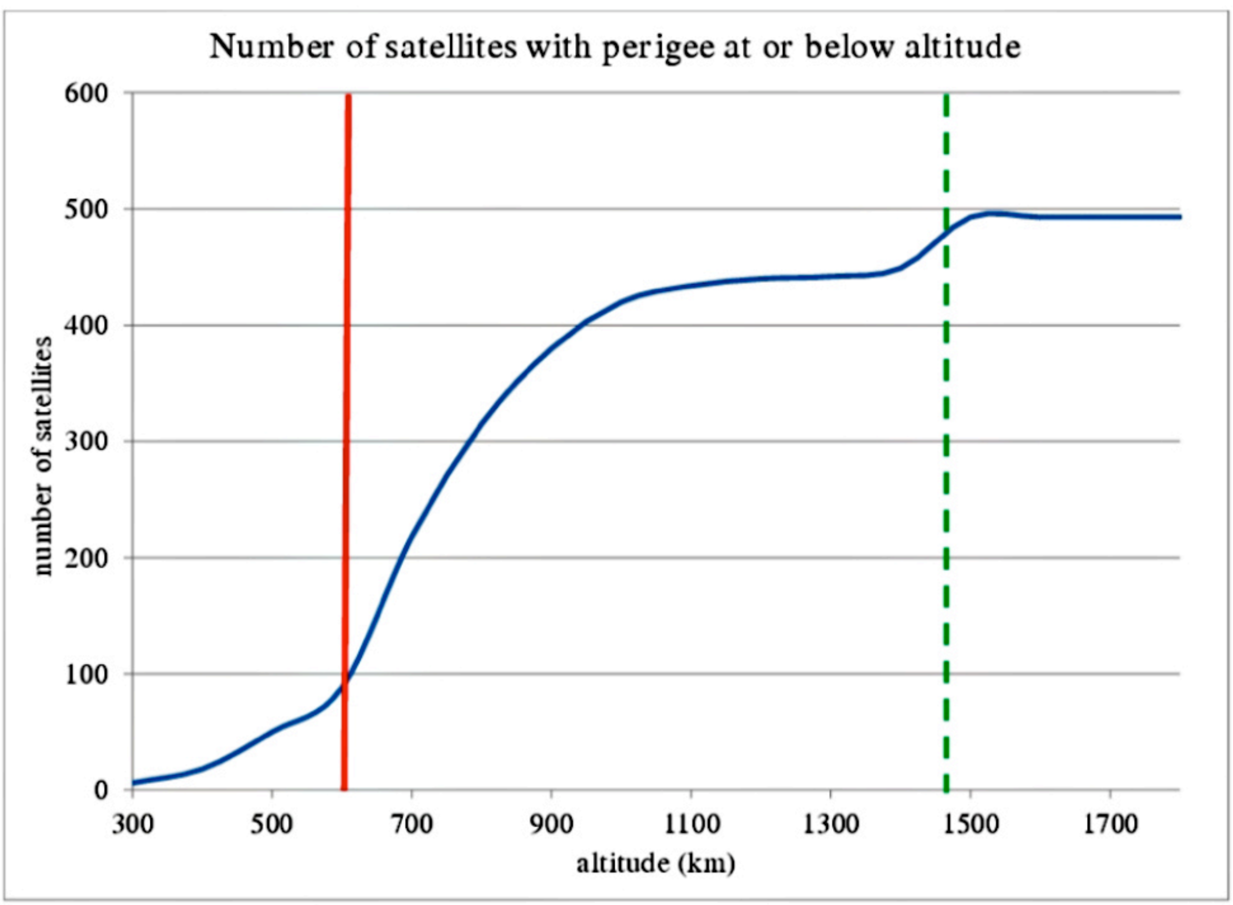

Table 3. Number of actively operating satellites in low-earth orbits, categorized by primary users.

Country	Civil	Government	Commercial	Military	Total
China	5	36	--	8	49
Russia	2	2	9	30	43

of SM-3 IIB interceptors planned for 2020, Aegis warships are capable of carrying large numbers of interceptors—cruisers have 122 launch tubes and destroyers have 90 or 96 each.[12] This would support a large scaling-up. Block II interceptors are designed to fit in all launch tubes.

The number of ASAT-capable SM-3 missiles can be scaled up and their configuration changed more rapidly and less expensively than the GBI missiles. While GBI interceptors cost about $70 million each, the estimated procurement cost for each SM-3 Block IIA missile is $20-24 million. While locating a new GBI missile site in a different location would take greater than five years for construction, the sea-based SM-3 missiles can be readily moved to the theater in which they are needed.[13]

The PAA system is highly mobile. The 43 planned Aegis ships could be positioned optimally to stage a "sweep" attack on a set of satellites nearly at once.

This potentially large ASAT capability can be compared to the satellite inventory of the two heaviest space users after the United States, which owns just shy of half of actively operating LEO satellites. Satellites stationed in LEO perform important civil and military functions; this is where most earth-observing, reconnaissance and signals intelligence, and weather satellites orbit. Table 3 shows the number of actively operating Chinese and Russian satellites in low-earth orbits. China has a total of 49 and Russia 43. (The United States owns 230 LEO satellites.) The PAA system as it gets to Phase 3 and 4 (see Table 1) could hold at risk a significant portion of either China's or Russia's low earth orbiting satellites, particularly if the numbers of Block II interceptors is increased or it is considered in concert with GMD.

Another important point is that the PAA system is highly mobile. The 43 planned Aegis ships could be positioned optimally to stage a "sweep" attack on a set of satellites nearly at once, rather than a sequential set of attacks as satellites moved into range of fixed interceptor sites. This positioning flexibility also means that the SM-3 missiles would not have to expend much of their thrust going cross-range and could retain the ability to reach the highest LEO satellites. (The more powerful GMD interceptors also could use some of their fuel to reach out laterally over thousands of kilometers, allowing them to hit satellites in orbits that do not pass directly over the GMD missile fields in Alaska and California.)

The Way Forward

While the primary purpose of the PAA system is not ASAT, as conceived it will be the largest destructive ASAT capability ever fielded and can hold a significant portion of any other space actor's space assets at risk. While some may describe the capability as "latent," it has been clearly demonstrated in Operation Burnt Frost. At the same time, international law treating the interference or destruction of satellites is only very weakly elaborated.

Some restraints on using the PAA system as an ASAT weapon do exist. Operation Burnt Frost required a modification of the missile defense software in order to perform the ASAT intercept and this reportedly will not become a standard option. However, no formal U.S. policy exists that renounces deploying this option, either, and other countries will assume that this change could readily be made to give any Aegis interceptor the ability to intercept satellites.

Additionally, the United States is clearly aware of the debris consequences of using kinetic energy interceptors to destroy satellites. For example, the destruction of a single 10-ton satellite could by itself double the total amount of large debris currently in low earth orbit.[14] This is a major reason why the United States prefers non-destructive ASAT options. It is therefore unlikely to use the PAA as an ASAT weapon simply to signal intent or in any situation outside of a major conflict.

But the existence of this capability also makes significantly less likely the possibility that other countries will also refrain from building such systems. The hit-to-kill intercept technology used by China for its January 2007 satellite destruction was apparently developed as a system that could be used either for ballistic missile defense or ASAT attacks. It is likely that China's first ballistic missile defense test on January 11, 2010, used this same technology.[15] India is also developing a hit-to-kill ballistic missile defense system which could also serve an ASAT role. Long-standing restraint regarding such systems has been weakened.

The Aegis-based missile defense system is also likely to be owned by other countries besides the United States. The Aegis system's interceptor technology is being codeveloped

and operated by Japan, and Japan is modifying all six of its Aegis destroyers with the updated Aegis BMD system. In June 2011, Japan agreed in principle to the export of the codeveloped SM-3 Block IIA missile to other countries,[16] clearing the way for the expected sale of the Aegis BMD system to additional users, including several European countries as well as South Korea and Australia.[17] Given the intrinsic ASAT capability of this system, the United States should review carefully its plans to sell this capability to other countries.

At the same time, the United States is grappling with what to do to address its outstanding space security issues. The National Security Space Strategy outlines a strategy for protecting U.S. interests in space, including supporting the development of norms of responsible behavior for space-faring nations, and increasing the ability of the U.S. military to continue to operate despite interference with its satellites by an adversary.[18] The United States is engaging in diplomatic initiatives such as the effort to create an International Code of Conduct for Outer Space Activities and the United Nations Group of Governmental Experts forum on confidence-building and transparency measures to improve space security and sustainability. However, none of these efforts yet imagine restrictions on "hardware" like missile defense interceptors, and are focused instead on creating norms of behavior. (Even the Russian-Chinese draft treaty on space weapons does not restrict ground-based missile defenses.)

Few limits or guidelines exist on technologies suited to ASAT use and devising effective limits on them becomes increasingly difficult as more weapons are developed and tested and more countries develop policy rationales and military doctrine for using them. Serious efforts to strengthen them should be put forth by all spacefaring nations; such discussions have not taken place for many years.

In addition to strengthening the legal and normative framework, space security requires thoughtful limits on the most dangerous technology. One way to address the inherent ASAT capability of the PAA is to restrict the burnout velocity of the deployed SM-3 missiles and to discontinue the Block II program.

A primary rationale for the high-speed Block II interceptors is to enable "early intercept"—the capability to intercept the attacking missiles after their launcher burns out (post-"boost phase") but before they are able to release countermeasures. However, the Defense Science Board, in an unclassified summary of its report on early intercept states that:

> *Intercept prior to the potential deployment of multiple warheads or penetration aids –the principal reason often cited for EI – requires Herculean effort and is not realistically achievable, even under the most optimistic set of deployment, sensor capability, and missile technology assumptions.*

While the study cites other capability-enhancing or cost-reducing scenarios that the longer-range interceptors could provide, the authors cede that successful operation of midcourse missile defense requires addressing the as-yet-unsolved countermeasures problem.[19] And the Block II missiles do not do so.

While the SM-3 Block II missiles will not solve the countermeasures problem by providing an early intercept capability, they could still have a theoretical capability to intercept Russian and Chinese long-range missiles; this can complicate Russian and Chinese reductions in nuclear weapons.[20] Limiting the allowed burnout speed of the SM-3 missiles would therefore not sacrifice any new capability, and would also avoid the problems that deploying an unlikely-to-be-used but still provocative ASAT system would.

The space environment needs more protection, satellites face growing risks, and space activities continue to be a potential source of mistrust and tension. Making significant progress requires making forward-looking choices. ■

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REFERENCES AND NOTES

[1] It is unlikely these software changes were significant and likely just provided infrared signatures of a satellite for the seeker and eliminated any instructions to ignore satellites. General Cartwright said in a press briefing that the physical modifications were instrumentation; this is presumably to provide information about the test. "Destruction of Spy Satellite." February 21, 2008. C-SPAN, c-spanvideo.org.

[2] In 1982, the Soviet Union conducted its last test of its Co-Orbital antisatellite weapon. In 1985, the United States destroyed an aging weather satellite using a direct-ascent kinetic kill interceptor launched from an F-15 airplane. Grego, L. "A History of Anti-satellite Programs" January 2012. Union of Concerned Scientists.

[3] Russia and China introduced their draft "Treaty on the Prevention of the Placement of Weapons in Outer Space, the Threat or Use of Force Against Outer Space Objects" on February 12, 2008. http://www.reachingcriticalwill.org/legal/paros/wgroup/PAROS-PPWT-factsheet.pdf The treaty forbids "hostile action against outer space objects including, inter alia, those aimed at their destruction, damage, temporarily or permanently injuring normal functioning, deliberate alteration of the parameters of their orbit, or the threat of these actions."

[4] Christina Rocca, U.S. ambassador to the CD, told the delegates in Geneva on February 13, 2007, that "we continue to believe that there is no arms race in space, and therefore no problem for arms control to solve." Statement delivered to the United Nations' Conference of Disarmament on Prevention of an Arms Race in Outer Space. Geneva, February 13. Online at *http://www.reachingcriticalwill.org/political/cd/speeches07/1session/Feb13USA.pdf*.

[5] O'Rourke, Ronald. "Navy Aegis Ballistic Missile Defense (BMD) Program: Background and Issues for Congress." December 22, 2011. Congressional Research Service. Available at http://www.fas.org/sgp/crs/weapons/RL33745.pdf , accessed Feb. 1, 2012.

[6] Ibid.

[7] At an April 23, 2008, hearing of the Defense Subcommittee of the Senate Appropriations Committee, General Henry Obering, director of the Missile Defense Agency, testified as follows: "It took us a couple weeks to analyze, and it turned out that both the ground-based midcourse THAAD and the Aegis all had capability, if they were modified, to go do this mission [to shoot down the failed USA 193]. The Aegis was the easiest to modify and also represented the most flexibility and the minimum impact to our program overall."

[8] Ground-Based Midcourse Defense Fact Sheet. Missile Defense Agency. Accessed February 1, 2012. http://www.mda.mil/global/documents/pdf/gmdfacts.pfd

[9] Wright, D. and Grego, L. "Anti-Satellite Capabilities of Planned U.S. Missile Defense Systems." *Disarmament Diplomacy* Issue No. 68, December 2002-January 2003.

[10] For an extensive discussion of countermeasures to midcourse missile defenses, see A. Sessler et al., *Countermeasures: A Technical Evaluation of the Operational Effectiveness of the Planned U.S. National Missile Defense System*, April 2000, Union of Concerned Scientists.

[11] The satellite information comes from the UCS Satellite Database, January 2012 edition. Available at http://ucsusa.org/satellites.

[12] The number of launch tubes depends on how many cells were used to host loading cranes.

[13] O'Rourke, Ronald. "Navy Aegis Ballistic Missile Defense (BMD) Program: Background and Issues for Congress." December 22, 2011. Congressional Research Service. Available at http://www.fas.org/sgp/crs/weapons/RL33745.pdf , accessed Feb. 1, 2012.

[14] See Wright, D. "Space Debris." *Physics Today*. Vol. 60, No. 10, October 2007, pp. 35-30.

[15] See Jacobs, A., and J. Ansfield. 2010. "With defense test, China shows displeasure of U.S." *New York Times,* January 12. See also the blog post and the references therein at *China's missile defense interceptor program: An independent Chinese analysis.* Online at *http://thetaiwanlink.blogspot.com/2010/01/chinas-missile-defense-interceptor.html*, accessed on September 19, 2010.

[16] Japan requires three conditions for the export—that third-party recipients of the technology have appropriate domestic systems for export control and information integrity, that they are members of international frameworks on these matters, and that the transfer benefits Japan's security, though it is not clear by what process these conditions are determined to be met.

[17] O'Rourke, Ronald. "Navy Aegis Ballistic Missile Defense (BMD) Program: Background and Issues for Congress." December 22, 2011. Congressional Research Service. Available at http://www.fas.org/sgp/crs/weapons/RL33745.pdf , accessed Feb. 1, 2012.

[18] Text of the National Security Space Strategy and related documents are available at http://www.defense.gov/home/features/2011/0111_nsss/

[19] The Defense Science Board study states that "Although not analyzed in detail during the course of the study, it is clear that the successful operations [of cost-effective ballistic missile defense] is predicated on an ability to discriminate (in the exo atmosphere) the missile warhead(s) from other pieces of the offensive missile complex, such as rocket bodies, miscellaneous hardware, and intentional countermeasures. The importance of achieving reliable midcourse discrimination cannot be overemphasized."

[20] Butt, Y. and Postol T. *Upsetting the Reset: The Technical Basis of Russian Concern Over NATO Missile Defense.* Federation of American Scientists Special Report No. 1, September 2011.