Missile Defense Advocacy Alliance
Spring 2016

U.S. BALLISTIC MISSILE DEFENSE

An Overview of Current and Future Ballistic Missile Defense Capabilities

Authors

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with an Introduction by Brig Gen (ret) Kenneth Todorov

Missile Defense Advocacy Alliance

Mission Statement

MDAA's mission is to make the world safer by advocating for the development and deployment of missile defense systems to defend the United States, its armed forces and its allies against missile threats.

MDAA is the only organization in existence whose primary mission is to educate the American public about missile defense issues and to recruit, organize, and mobilize proponents to advocate for the critical need of missile defense. We are a non-partisan membership-based and membership-funded organization that does not advocate on behalf of any specific system, technology, architecture or entity.

U.S. BALLISTIC MISSILE DEFENSE

An Overview of Current and Future BMD Capabilities

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MDAA
Missile Defense Advocacy Alliance

About MDAA

MDAA is a non-profit organization which seeks to generate public support for the continued testing, development and deployment of missile defense systems to protect our country and our allies. The organization seeks to educate the general public with respect to missile defense issues and the urgent need for it.

MDAA is a non-partisan organization which does not advocate for a particular company, system or product. In order to act impartially, MDAA is governed by a Board of Directors which does not have a financial interest in the decisions the United States Government makes with regard to its missile defense systems. Hence, MDAA's Board of Directors is populated with business professionals drawn from outside the defense industry who offer the perspective of citizens who wish to be protected.

Riki Ellison, Chairman and Founder

Mr. Riki Ellison is the Founder and Chairman of the Missile Defense Advocacy Alliance; a non-profit organization launched in 2002 with a singular purpose and mission to drive for the deployment, development and evolution of missile defense. Since its founding, the organization has grown to over 14,000 members across the world and has emerged as the top lay expert voice on missile defense. Mr. Ellison has toured 25 U.S. missile defense tests, visited U.S. missile defense sites over 300 times and has advocated for missile defense in 43 states and 22 countries.

As a renowned expert among his peers in the field of missile defense, Mr. Ellison is frequently sought after for his expertise by administration, military officials, congressional members, international and national press and policymakers of the United States. He has been interviewed by top media outlets in the nation and internationally including but not limited to: BBC, CNN, C-SPAN, FOX News, Wall Street Journal, New York Times, and Reuters. Mr. Ellison has helped pass over 10 Congressional and State Resolutions on behalf of missile defense.

Amongst the achievements of Mr. Ellison is the creation and building of two historic missile defense and veteran public memorials. One memorial is located at Vandenberg AFB in California honoring President Ronald Reagan and the other located at the Pacific Missile Range Facility in Kauai, Hawaii dedicated with the late Senator Daniel Inouye. Mr. Ellison also established the annual "Missile Defender of the Year Award Ceremony." The Missile Defender of the Year Award is given to the best missile defense operators around the world.

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MDAA's Ronald Reagan Missile Defense Site at Vandenberg Air Force Base, California

Photo: Associated Press

Introduction

The specter of a ballistic missile attack on the United States and its allies, or at the very least the threat of such an attack, continues to grow. Threat systems from rogue nations and potential adversaries around the world continue to mature in quality and quantity. As potential adversaries improve their missile technologies, they are demonstrating more sophisticated and reliable systems with increasing complexity, range, and accuracy. All of that makes understanding the complex and highly technical world of ballistic missile defense especially critical for policy makers, government professionals, and warfighters alike.

This comprehensive overview of the Ballistic Missile Defense System is an excellent reference for anyone interested in furthering the cause of freedom around the world. Whether one has long been actively engaged in the discussion surrounding this critical mission area, or is seeking to further their grasp of its intricacies, this guide will serve as an excellent reference for understanding how these complex systems work and interact with each other.

The "story" of ballistic missile defense is not entirely new. Ballistic missiles emerged as a sought-after and persistent threat with the launch of the V-2 long-range, guided ballistic missile in June 1944. After the Second World War, technological advances in guidance systems, propulsion, reliability, and the miniaturization of nuclear, chemical, and biological warheads paved the way for ballistic missiles to take on a new significance and become key strategic delivery vehicles for weapons of mass destruction.

The evolving threat posed by ballistic missiles led to the research and development of missile defenses, which the United States began exploring in the 1950s. The ballistic missile threat increased in subsequent decades as missile technology proliferated around the globe and many states hostile to the U.S. began pursuing and acquiring ballistic missile capabilities. With the increased proliferation of ballistic missiles and a changing threat environment throughout the 1990s, the need for the United States to deploy advanced radar and missile defense systems grew, spurring the deployment of a national ballistic missile defense system in the mid-2000s. Other, equally important regional missile defense systems have been developed simultaneously.

Given the important role that ballistic missile defense plays in the national security of the United States, MDAA has developed this overview to provide a general understanding of the ballistic missile threat and the defensive systems used by the United States.

This overview is a broken into five main sections, each of which deals with a different aspect of missile defense and the ballistic missile threat. The first section describes the ballistic missile threat to the United States by providing an overview of ballistic missiles and the threat posed by nations such as North Korea and Iran. The second section looks at numerous missile defense systems deployed by the United States and the types of missiles they are designed to intercept. The third section outlines U.S. sensor systems used to detect and track incoming ballistic missiles, while also providing fire control support for missile defense interceptors. The fourth section covers ways in which the United States cooperates with other nations on missile defense research, development, and the deployment of sensors and defensive systems. The fifth and final section delves into future ballistic missile threats and developing defensive capabilities.

The information provided in this overview is not meant to promote a particular missile defense or radar system and is not designed as an in-depth technical guide of the systems. Rather, this overview is intended to provide members of Congress, their staff, and the public at-large with a general understanding of missile defense and radar systems, the ballistic missile threats facing the U.S. today, and the important role these systems play in defending the United States homeland, our deployed forces, and our partners and allies around the world.

To ensure our success, defending our interests and those of our friends and allies around the globe will require a broad mix of missile defense capabilities and approaches. This mix will include both defense and offense, passive and active measures, and kinetic and non-kinetic technologies. All of this will need to be integrated and exercised in an effective joint and combined warfighting force. For anyone concerned with being a part of the important conversations surrounding how best achieve that end, this guide will surely become an essential reference.

Kenneth E. Todorov, Brig Gen, USAF (Ret)
Former Deputy Director, Missile Defense Agency

Historical Overview

In 1960, Nike-Hercules scored a direct hit on a target missile in the sky over White Sands becoming the first U.S. system to successfully intercept a ballistic missile.

Photo: xpda.com

Early Ballistic Missile Defense Efforts

Interest in developing a capability to defend against the threat of ballistic missiles began as early as the mid 1940s as German “V” rockets began striking targets in Europe. The first V-1 rocket struck London on June 13, 1944 followed by the first V-2 attack on September 8, 1944. [1] By the time the Germans launched their final missile attack on London on March 27, 1945, the “V” weapons had caused over 30,000 civilian casualties and left hundreds of thousands homeless. [2] The earliest efforts to defend against the “V” weapons included massed batteries of anti-aircraft weapons and the use of fast RAF fighter aircraft to shoot or 'tip' down the incoming flying bombs before they reached their targets. [3] The earliest U.S. Army Air Force efforts to research anti-ballistic missile (ABM) systems occurred from 1945-1949 and was a research project to develop surface to air missiles called ground-to-air pilotless aircraft (GAPA). [4] During this time two additional Army Air Force BMD projects called Thumper and Wizard were commissioned in March and April 1946 respectively. [5] The Thumper project was awarded to General Electric for the study of BMD interceptor weapons using the collision intercept method for destroying a ballistic missile, while Wizard was contracted with the University of Michigan's Aeronautical Research Center. [6] These early BMD projects were eventually ended due to the limited technological capabilities of the time.


Photo: U.S. Army

Early U.S. ABM Systems - Project Nike

As World War II ended and the Cold War began, the United States was eager to develop technology to defend against Soviet ballistic missiles. To that end, Project Nike became the first system to achieve a number of air and ballistic missile defense milestones. The U.S. Army deployed the world’s first operational anti-aircraft surface-to-air missile system in 1954, called Nike-Ajax. [7] Nike-Ajax was first deployed in Maryland and expanded to nearly 200 additional strategic sites within the U.S. over four years for the purpose of defending against Soviet bombers. [8] Nike Ajax used high-explosive fragmentation warheads to destroy targets. On June 3, 1960 the successor to Nike-Ajax, Nike-Hercules, further advanced the capability when it scored a direct hit on a target missile in the sky over White Sands, becoming the first system to successfully intercept a ballistic missile. [9] The next major development in the program, Nike-Zeus, was the first U.S. attempt at creating an ABM system. [10]

Although Nike-Zeus demonstrated a capability to defeat long range ballistic missiles, the system was never deployed due to a number of concerns. First, Zeus utilized nuclear warheads due to its lack of hit-to-kill accuracy and it was unknown how the nuclear detonation would impact the rest of the system. [11] Second, the system was vulnerable to decoys and countermeasures because its radar was only capable of tracking one target at a time. [12] The Nike-Zeus program was re-directed toward a new effort called Nike-X. Nike-X featured the Multifunctional Array Radar (MAR), a phased array radar designed to address the issues that made Zeus vulnerable to multiple incoming targets. [13] Following China’s first successful nuclear test in 1964, then Secretary of Defense Robert McNamara announced the deployment of a thin Nike-X ABM system he renamed Sentinel. [14] As a thin deployment, Sentinel was to be installed originally at 17 geographical locations, among which were the metropolitan areas of Boston, Chicago, Detroit, Seattle, San Francisco, and Los Angeles. [14] By 1975, the Sentinel program became even more limited in scope as it was renamed Safeguard and deployed to provide protection of the Minuteman sites and only light overall protection of the U.S. population. [15]

Strategic Arms Limitation Talks/Anti Ballistic Missile Treaty (1972)


Photo: Nixon Library

Leonid Brezhnev of the Soviet Union meets with President Richard Nixon

In the late 1960’s the Soviet Union expanded its strategic nuclear forces and also began the development of its own ABM systems to protect Moscow. In 1967, President Lyndon Johnson called for strategic arms limitations talks (SALT) with Soviet Premier Alexei Kosygin to limit the development of both offensive and defensive strategic systems. [16] President Richard Nixon continued the SALT talks upon entering the White House and signed the Anti-Ballistic Missile (ABM) Treaty and interim SALT agreement on May 26, 1972, in Moscow with Soviet General Secretary Leonid Brezhnev. [17] SALT I was the first arms control agreement completed during the Cold War which placed a limit on the number of nuclear missiles the U.S. and Soviet Union could deploy. The ABM Treaty limited strategic missile defenses to 200 interceptors each and allowed each side to construct two missile defense sites, one to protect the national capital, the other to protect one ICBM field. [18]

Photo: Reagan Library

The Strategic Defense Initiative (1983)

In the early 1980's, fear that the Soviet Union had achieved a nuclear first strike capability led the Joint Chiefs of Staff to recommend that President Ronald Reagan begin developing plans for ballistic missile defense capabilities. [19] On March 23, 1983, President Reagan delivered an address to the nation outlining an ambitious new plan for ballistic missile defense called the Strategic Defense Initiative (SDI). During the speech, President Reagan called for a defensive capability that would render nuclear weapons "impotent and obsolete." [20] SDI was dubbed "Star Wars" as it called for advanced space-based technologies and directed energy capabilities. In 1984, the Strategic Defense Initiative Organization (SDIO) was established to begin Research and Development (R&D) efforts to create a number of programs such as Brilliant Pebbles, a non-nuclear, space-based, boost phase anti-missile system. [21] Ultimately, many of the most ambitious SDI technologies were set aside due to political pressure and U.S. obligations to limit testing and development of BMD technology. While the Reagan Administration argued that it was able to test and develop BMD systems under a "broad interpretation," many in Congress, led by Senator Sam Nunn, argued that such an interpretation violated the spirit of the treaty. [22]

After the Soviet Union

During the January 29, 1991 State of the Union Address, citing the success of the Patriot missile defense system during the Gulf War, President George H.W. Bush mandated that the "SDI program be refocused on providing protection from limited ballistic missile strikes, whatever their source." [23] This directive led to the development of Global Protection Against Limited Strikes (GPALS), aimed at stopping small ballistic missile attacks on America and thwarting limited strikes against U.S. troops with the use of theater ballistic missiles. GPALS represented a new Post-Cold War mentality in the United States that focused more on limited theater ballistic missile strikes rather than an all-out Soviet ICBM assault. [24] However, the GPALS concept was ultimately cancelled in 1993 by the Administration of President Bill Clinton. Rather than taking a global approach against a range of ballistic missile threats, President Clinton's 1993 "Bottom-Up Review" called for a BMD strategy that "focused on the deployment of advanced theater missile defenses to protect forward-deployed U.S. forces and provision of the capability for a limited defense of the United States." [25]

New Geostrategic Challenges

In the late 1990s, Congress became increasingly concerned by the developing ballistic missile programs of so-called "rogue nations" such as Iran and North Korea. This was despite a 1995 National Intelligence Estimate (NIE) stating "No country, other than the major declared nuclear powers, will develop or otherwise acquire a ballistic missile in the next 15 years that could threaten the contiguous 48 states and Canada." [26] In response, Congress mandated the creation of two separate panels to investigate the threat ballistic missiles posed to the United States.

The first panel, established in 1996 and led by former CIA Director Robert Gates, conducted an independent review of the 1995 NIE and presented its findings to the Senate Select Committee on Intelligence. The Gates Panel, while critical of the '95 NIE's methodology, concluded that "the United States is unlikely to face an indigenously developed and tested intercontinental ballistic missile threat from the Third World before 2010." [27]

The second panel, led by former Secretary of Defense Donald Rumsfeld, issued their final report on the "Commission to Assess the Ballistic Missile Threat to the United States" to Congress in 1998. The Rumsfeld Panel drew a number of conclusions regarding the ballistic missile threat to the United States including:

- Concerted efforts by a number of overtly or potentially hostile nations to acquire ballistic missiles with biological or nuclear payloads pose a growing threat to the United States
- The threat to the U.S. posed by these emerging capabilities is broader, more mature and evolving more rapidly than has been reported in estimates and reports by the Intelligence Community
- The Intelligence Community's ability to provide timely and accurate estimates of ballistic missile threats to the U.S. is eroding
- The warning times the U.S. can expect of new, threatening ballistic missile deployments are being reduced [28]

In August of 1998, just months after the Rumsfeld panel submitted its report to Congress, North Korea launched a three-stage Taepodong-1 rocket under the guise of a satellite launch. [29] North Korea's launch further motivated Congress to address the ballistic missile threat. The following year, Congress passed the National Missile Defense Act of 1999, which declared that it would be "the policy of the United States to deploy as soon as is technologically possible an effective National Missile Defense system capable of defending the territory of the United States against limited ballistic missile attack." [30]

Withdrawal from the ABM Treaty

At the end of 2001, the administration of President George W. Bush made the decision to withdraw from the 1972 ABM Treaty. This decision paved the way for the deployment of many of the systems discussed in this overview. Further historical context since 2001 will be discussed in the profiles of each of the systems.


Credit: armscontrolnow.org


Credit: Martin H. Simon-Pool/Getty Images

Left: President George W. Bush announces U.S. withdrawal from the Anit-Ballistic Missile Treaty on December 13, 2001. Right: President Barack Obama announces the European Phased Adaptive Approach on September 17, 2009.

Section 1 - Ballistic Missile Basics

Photo: JapanTimes.co.jp

1.1 Ballistic Missile Basics

The Iranian Revolutionary Guard Corp fires a long-range ballistic missile in March of 2016

What is a ballistic missile? Ballistic missiles are a means to rapidly and accurately deliver a lethal payload to a target. The lethal payload can include conventional explosives, or a biological, chemical or nuclear warhead. Ballistic missiles are very cheap, which makes their proliferation more likely and ensures that their numbers will continue rising in the future.

Once its fuel has been consumed, the ballistic missile follows an elliptical orbit around the center of the Earth, defined strictly by the combination of velocity/flight angle at burnout and the Earth's gravity. Ballistic missiles can be solid or liquid propelled. Liquid propellants are cheaper, but they are less stable, more difficult to store, and more toxic than solid propellants, which are more expensive, but more stable and easily maintainable. Hybrid fuels are currently under development, combining the benefits of solid- and liquid-propelled ballistic missiles.

Operational ballistic missiles are deployed in missile silos, on submarines, ships, planes and land-mobile launchers (trucks or railcars). Mobile missiles are favored by many nations because they can be hidden in places such as underground tunnels or dense forests, which greatly increases their survivability. The mobility of road- and rail-based missile delivery vehicles and ballistic missile submarines makes it more difficult to track and predict the location from which the missile will launch. This uncertainty increases the detection and intercept difficulty for missile defense systems and radars.

Longer-range ballistic missiles are often designed to carry Multiple Independently-targeted Reentry Vehicles (MIRVs). MIRVed missiles can hold up to 10 warheads, which reenter the Earth's atmosphere at very high velocities, on the order of 4-5 miles per second. A MIRVed missile is more difficult to intercept in the terminal phase of flight since it produces up to 10 targets instead of one. In addition to MIRVs, some countries also develop maneuverable reentry vehicles (MaRVs), which further complicate intercept attempts by shifting targets during their flight.

Ballistic missiles are composed of one or more stages. Multiple-stage missiles, which are configured so that each stage has its own independent propulsion system, are used for longer range missions. Intercontinental ballistic missiles (ICBMs) typically have two or three stages with powerful liquid-or solid- propelled engines that launch the payload on a ballistic trajectory towards its target, as well as a post-boost vehicle (PBV) with a much smaller propulsion system. The technology needed to separate each of the stages in high velocities and under difficult atmospheric conditions is relatively sophisticated and often tightly controlled, making it difficult and time-consuming for many countries to acquire this technology.

Ballistic Missile Classes and Ranges Ballistic Missiles are typically classified into the following categories:

CLASSIFICATION	**ABBREVIATION**	**RANGE**
Short Range Ballistic Missile	SRBM	<1000 km
Medium-Range Ballistic Missile	MRBM	1000-3000 km
Intermediate-Range Ballistic Missile	IRBM	3000-5000 km
Intercontinental Ballistic Missile	ICBM	> 5500 km
Submarine Launched Ballistic Missile	SLBM	Varies

Missile Components

Ballistic missiles are made up of three essential elements. The first element is a propulsion system, which provides the energy necessary to reach the target, the second is a guidance system, which steers the missile during powered flight and ensures the correct initial conditions for the ballistic trajectory and finally the payload detonates to destroy the target.

Propulsion Rocket propulsion involves combining fuel and an oxidizer in a combustion chamber, in which chemical reactions produce a high-pressure, high temperature gas. Exhausting that gas produces thrust that propels the missile. Ballistic missiles can use solid or liquid propellant rocket propulsion systems. Modern missile systems tend to use solid propellants because of their simplicity of operation and reduced logistical requirements; however, some countries have greater access to liquid propellant technology and, therefore, continue to develop new liquid propellant missiles.

Guidance System The accuracy of a ballistic missile depends on its ability to achieve an exact velocity and location in space at the end of its powered flight. Ensuring that this velocity and location are precisely attained is the job of the guidance and control system. Throughout the powered phase of flight, the instruments in the inertial navigation system (INS) must continually sense all the components of the missile’s acceleration. The guidance computer uses these sensed accelerations to determine the missile’s “state” (velocity, location, and orientation) and sends corrective messages to the missile’s steering system to eliminate deviations from the required flight profile.

Payload The function of the ballistic missile payload subsystem is to ensure that the weapon reaches the target and detonates at the correct time and place. Ballistic missile payloads can be nuclear, conventional, or chemical/biological. Chemical and biological weapons are more often incorporated into payload systems for short-range ballistic missiles, as the effectiveness of these payload designs is speculative when employed for longer ranges.

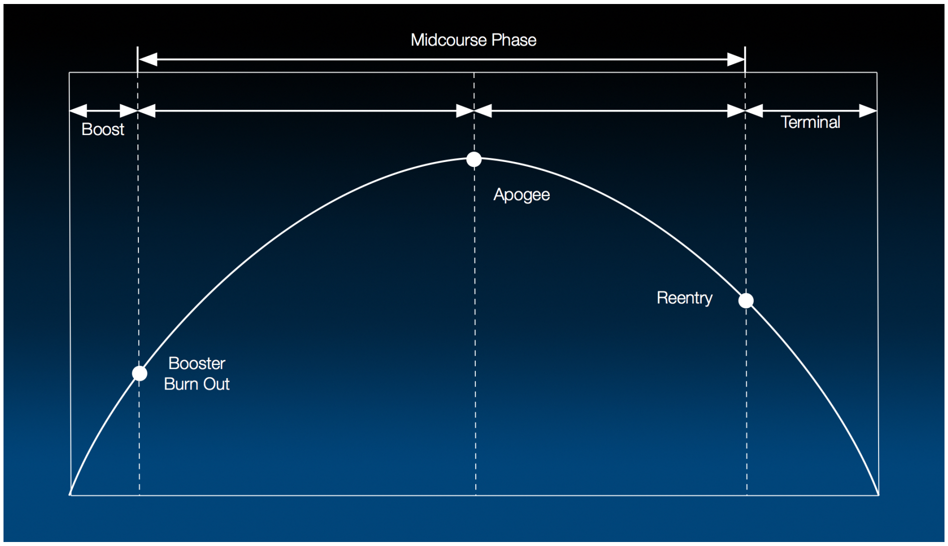
Phases of Flight

Ballistic missile trajectories are typically divided into three phases of flight called the boost phase, midcourse phase and the terminal phase.

Boost Phase The first phase of a ballistic missile’s flight is called the boost phase. This phase lasts from 1 to 5 minutes as the missile booster burns and the missile ascends in an arching trajectory toward its target. The exhaust from the missile is bright and hot, making the missile easy to detect and track during this time. However, intercepting a missile in this phase is difficult since interceptors must be in close proximity to the launch area.

Midcourse Phase The midcourse phase begins when the enemy missile's booster burns out and it begins coasting in space towards its target. This phase can last as long as 20 minutes, allowing several opportunities to destroy the incoming ballistic missile outside the earth's atmosphere. [1]

Terminal Phase This phase is very short and begins once the missile reenters the atmosphere. It is the last opportunity to make an intercept before the warhead reaches its target. Intercepting a warhead during this phase is difficult and the least desirable of the phases because there is little margin for error and the intercept will occur close to the intended target. [2]



North Korea has tested a number of long range rockets under the guise of satellite launches. The most recent occurred in February of 2016.

Photo: Reuters

1.2 North Korean Missile Threat

North Korea's Ballistic Missile Arsenal The DPRK's ballistic missile capabilities have progressed significantly over the last few decades, evolving from artillery rockets in the 1960s, to short- and medium-range ballistic missiles in the 1980s and 90s, and finally developing and testing long-range ballistic missiles in the late 1990s and 2000s. [1] In 1965, North Korean leader Kim Il Sung chose to initiate a ballistic missile program by increasing the military budget and obtaining technical assistance from his Communist allies—the Soviet Union and China. With expanded funding for its ballistic missile program and technical assistance from its allies, the isolationist state was able to steadily progress its ballistic missile capabilities throughout the following decades. By the time the Soviet Union collapsed in 1991, North Korea had obtained enough outside expertise to sustain—and improve—an indigenous missile development program. In 1998, after an attempted satellite launch with a multi-stage rocket, North Korea demonstrated an improving technical capability and a willingness to develop long-range missiles that could target the United States homeland. North Korea continues to test and improve its ballistic missile capabilities and is an active proliferator of missile systems, components, and technology. [2] Iran has been a major recipient of North Korean ballistic missile technology.

Short Range Ballistic Missiles (SRBMs) The Kim regime possesses a variety of short-range ballistic missiles (SRBMs). The isolationist state currently employs three types of SRBMs: the KN-02, the Hwasong-5, and the Hwasong-6. [3] The KN-02 has a range of up to 120 km and is operational, putting military installations in South Korea at risk. Moreover, the KN-02 is believed to have a payload capacity between 250 and 500 kg. Other SRBMs employed by North Korea are the Hwasong-5 and the Hwasong-6, both of which were developed with Soviet assistance in the 1970s and 80s, and are speculated to have been tested and deployed. The Hwasong-5—also known as the Scud-B—has a range of 300 km and the Hwasong-6—also known as the Scud-C—has a range of 500 km. U.S. intelligence reports estimate that North Korea deploys over 600 scud missile variants. [4] Both of the Hwasong SRBMs may be capable of delivering biological, chemical, or nuclear payloads and striking anywhere in South Korea and small parts of southern Japan.

Medium-Range Ballistic Missiles (MRBMs) The Nodong missile, which Pyongyang began developing in the late 1980s based on the scud design, has an estimated range of 1,350-1,600 km and payload capacity of about 1000 kg. U.S. sources estimate that the DPRK has around 200 deployed Nodong missiles. [5] Japan is the likely target of the Nodong, however, it is believed that the medium-range ballistic missile (MRBM) is relatively inaccurate, having a "circular error probable" of 2 to 4 km. The Nodong is assumed operational, and is believed to have been tested in 2006, 2009, and 2014. North Korea's Nodong MRBM could potentially be used to strike anywhere in South Korea or parts of southern Japan.

The intermediate-range Musudan is exhibited during a North Korean military parade

Intermediate-Range Ballistic Missiles (IRBMs) Pyongyang is believed to have two types of intermediate-range ballistic missiles (IRBMs): the Taepodong-1 and the Musudan. The Taepodong-1 was North Korea's first multi-stage ballistic missile and is currently operational and deployed. The IRBM has an estimated range of 2,200 km and a payload capacity between 100 and 200 kg. [6] Satellite photographs of the Taepodong-1 have caused experts to speculate that the intermediate-range missile has two stages. The first stage consists of components from the medium-range Nodong missile and the second stage is made up of components from the short-range Hwasong-6 missile. In 1998, a three-stage version of the Taepodong-1 was tested in an attempt to put a satellite into low earth orbit. During the test, the first two stages worked correctly, however, the third stage malfunctioned and the test was a failure. The DPRK's other IRBM is the Musudan. The Musudan—also known as the Nodong-B or the Taepodong-X—has a speculated range of 2,500 to 4,000 km and an estimated payload capacity of 1,200 kg. [7] [8] The likely targets of the Musudan are U.S. bases in the Pacific, Okinawa, and Japan. Little is known about the Musudan, but it is likely that the IRBM is not yet operational and still in the developmental phase. U.S. sources estimate that North Korea has fewer than 50 Musudan and Taepodong-1 IRBM missiles. IRBMs fired from North Korea can target South Korea and Japan along with U.S. military bases in the Pacific.

North Korea purportedly parades the KN-08 ICBM through the streets of Pyongyang in 2012

Intercontinental-Range Ballistic Missiles (ICBMs)
North Korea's known intercontinental-range ballistic missiles (ICBMs) are the Taepodong-2 and the KN-08. The Taepodong-2/Paektusan-2 is a two to three-stage ballistic missile with an estimated range of 6,000 - 9,000 km and a payload capacity of 100 to 500 kg. [9] The DPRK tested the Taepodong-2 in 2006, but the missile failed to perform to standards. Nonetheless, the Taepodong-2 is considered operational and has the capability to strike Alaska and the U.S. West Coast.

Recently, North Korea has developed and tested a three-stage version of the Taepodong-2 called the Unha that, according to Pyongyang, is a rocket designed to put a satellite into orbit. However, some experts speculate that the long-range rocket could be employed as a silo-based ICBM. If deployed as a ballistic missile, the Unha has a potential range of 10,000 km and is estimated to have a payload capacity of between 100 and 1,000 kg, meaning that the missile could be used to deliver a military payload to targets in the central United States. [10] The Unha has been tested four times: April 2009, April 2012, December 2012, and February 2016. [11] The rocket failed to put a satellite into orbit during the first two tests, but was successful during the last two. Despite the true intentions of the Kim regime, the successful tests of the Unha rocket demonstrated a North Korean ability to develop a multi-stage ballistic missile capable of striking the U.S. homeland. In April 2012, during a parade to honor its founder, Kim Il Sung, the DPRK displayed a new ICBM known as the KN-08. The KN-08 is a road-mobile ICBM that has never been tested, but experts estimate it has the potential to strike the continental United States with a nuclear payload. [12] The road-mobile capability of the KN-08 and the corresponding increase in launch area uncertainty present a significant challenge for U.S. and allied missile defense forces.

Submarine Launched Ballistic Missiles (SLBMs) The DPRK's submarine-launched ballistic missile (SLBM), the KN-11—also known as the Polaris-1, is still in the testing phase. The range and payload capacity specifications of the KN-11 are unknown, however, it is believed to be comparable to the Soviet single-stage liquid-fueled R-27 that has a range of 2,400 km and a 650 kg payload. In early 2016, state media footage released by North Korea showed the testing of an SLBM—likely the KN-11—however, the tests are reported to have been unsuccessful. [13] To complement its developing SLBM program, North Korea is also working on deploying a submarine capable of launching ballistic missiles. Currently, North Korea is in the process of reverse engineering a Soviet-era Golf-II class submarine, which, although obsolete by modern standards, has the capability to launch nuclear-armed ballistic missiles. While reports indicate that some North Korean test SLBMs were launched from submersible vessels, the Kim regime is likely years away from developing any operational ballistic missile submarines. [14] Moreover, if a fleet of submarines are developed based on the Golf-II design, it is likely that they will be outdated and easily detectable by more advanced submarine hunting equipment.

Cruise Missiles In the summer of 2014, North Korea released footage showing the launch of a cruise missile called the KN-09, which, according to the footage, appears to be a variant of Russia's Kh-35 anti-ship cruise missile. [15] If similar to the Russian Kh-35, Pyongyang's cruise missile variant has a range of about 130-140 km and travels at high speeds near the sea's surface. [16] The sea skimming KN-09 threatens U.S. and allied naval forces in the region, including American and Japanese Aegis missile defense vessels.

1.3 Iranian Missile Threat

Iran's Ballistic Missile Arsenal Since the Iran-Iraq War in the late 1980s, Iran has obtained and developed a sophisticated arsenal of ballistic missiles. Currently, Iran possesses short- to intermediate-range ballistic missiles, but intelligence reports indicate the nation is developing Intercontinental-Range Ballistic Missiles (ICBMs) as well, disguising efforts as a space launch program.

Short-Range Ballistic Missiles (SRBMs) Iran has a wide variety of one-stage Short-Range Ballistic Missiles (SRBM), all of which are deployed, road-mobile, and capable of delivering a nuclear payload. These road-mobile ballistic missiles can be launched from anywhere within Iranian territory and strike targets along its borders and in neighboring states. SRBMs in Iran's arsenal include the Shahab-1 and -2, the Tondar-69, the Fateh A-110, Fateh-313, the Muschak-200, and the Qiam-1.

Purchased from North Korea, the Shahab-1—also known as the Scud-B—was first deployed in the late 1980s during the Iran-Iraq War. [1] The liquid-fueled SRBM uses inertial guidance, has a range of around 300 km, and a payload capacity of about 1000 kg. The Shahab-2—also known as the Scud-C—was first obtained by Iran between 1990 and 1991. [2] It is liquid-fueled, has a range of 500 km, and a payload capacity of around 730 kg. Iran is speculated to possess 200 to 300 Shahab-1s and Shahab-2s.

The Tondar-69—also known as the CSS-8 (M-7)—is a solid-fueled SRBM that entered service in 1992. It is speculated that Iran purchased 200 CSS-8 (M-7) SRBMs from China in 1989, later renaming the missile the Tondar-69. [3] This SRBM uses inertial guidance, has a payload capacity of 190-200 kg, and a range of between 150 and 180 km. It is believed that the Tondar-69 will soon become obsolete, and estimates claim that only around 100 Tondar-69 missiles remain operational in Iran. [4]

The Fateh A-110 began development in 1995 and was designed to have greater accuracy than previous Iranian SRBMs. It is sold-fueled, inertial- and GPS-guided, and has a payload capacity of between 500 and 600 kg. Of the different Fateh A-110 variants, the Fateh A-110C has the longest range, with a maximum range of 300 km. The Fateh A-110 is solid fueled which makes it easy to transport and increases the possibility of Iran transferring it to Iranian-backed groups such as Hezbollah or Bashar al-Assad in Syria. In 2012, Iran transferred Fateh A-110 missiles to Syria and they were subsequently used against rebels fighting the Assad government. [5] Upgraded versions of the Fateh A-110—called the Hormuz 1 and Hormuz 2—were unveiled by Iran in May 2014 and appear to be equipped with improved guidance and countermeasure capabilities. [6]

The Fateh-313 is an Iranian-designed, short-range, surface-to-surface ballistic missile. It is a variation of the Fateh-110 series, featuring an improved guidance system with the ability to strike targets with pinpoint accuracy within 500 km. However, the accuracy of the Fateh-313 may come at the expense of payload size, as some experts believe the smaller nose section indicates it carries a payload of less than 500 kg.

The Fateh-313 has the capability and range to hit targets in neighboring Arab Gulf states. It also features a quicker launch capability and longer lifespan than earlier models. Iran mass produces and stockpiles the Fateh-313, increasing the size and scope of its ballistic missile arsenal, which is already the largest in the Middle East.

The Muschak-200—also known as the Zelzal-2—is a solid-fueled SRBM that Iran began to sell in 1996. [7] This SRBM has a payload capacity of between 500-600 kg and a range of 300 km.

The Qiam-1 is a liquid-fueled SRBM produced by Iran that was declared operational in 2010. [8] Reports speculate that the SRBM is a modified Shahab-2 designed to reduce the time for launch preparation. [9] Iranian state media claims it is also capable of carrying a multi-reentry vehicle warhead (MRV), which deploys multiple warheads in a pattern against a target to evade missile defense systems. [10] This SRBM is road-mobile, but also compatible with missile silos, and it is estimated that the Qiam has a range of between 700-850 km and a payload capacity of between 500-600 kg. [11]

An Iranian Shahab 2 missile is paraded in Tehran

Medium-Range Ballistic Missiles (MRBMs) Iran has four types of Medium-Range Ballistic Missiles (MRBM): the Shehab-3, the Sejjil, the Ghadr, and the Emad. These MRBMs have a range between 1,000 and 3,000 km, allowing them to strike targets throughout the Middle East and Southeast Europe.

The Shehab-3—particularly the 3A and 3B variants—is a liquid-fueled single-stage MRBM that is both road-mobile and silo capable. This MRBM is modeled after the North Korean No Dong, which was acquired by Iran in the 1990s. Iran examined and reengineered the No Dong, renaming it the Shahab-3. The Shahab-3 was first tested in 1998, and by 2005, Iran claimed to have the ability to produce the MRBM domestically. Improved variants of the Shahab-3 have ranges between 1,500 and 2,500 km and a payload capacity of around 1,200 kg. [12][13] It is speculated that Iran has 650 airframes, 45 mobile launchers, and 10 to 12 fixed launchers for the Shahab-3. [14]

The Sajjil—also known as the Ashura—is a solid-fueled two-stage MRBM that is road-mobile and developed indigenously by Iran. Development of the Sajjil began in the 1990s with assistance from China. It has a payload capacity of 750 kg and a range of between 2,200 and 3,000 km. Intelligence estimates claim that Iran has around 10-12 mobile launchers and 24 airframes. [15]

The Ghadr derives its design from the Shahab-3 and is estimated to have a range of between 1,800 and 1,900 km, however, little else is known about it. The payload capacity, type of propellant, and number of stages is uncertain. In June 2014, a U.N. Panel of Experts report stated that Iran had tested the Ghadr in November 2013 and January 2014. [16]

The Emad is a liquid-propelled road-mobile MRBM and, like the Ghardr, derives its design from the Shahab-3. It has a range of 1,700 km, can carry a payload weighing up to 750 kg, and is scheduled to be deployed some time in 2016. Reports claim that the Emad is Iran's first precision-guided MRBM, using a maneuverable reentry vehicle (MaRV) to hit within 500 m of its target. The Emad has improved accuracy because the MaRV compensates for reentry errors and contains sensors that allow the warhead to hone in on specific coordinates or target signatures. With the ability to change its flight path after launch, the MaRV also increase survivability, making it more difficult for ballistic missile defense systems to track the missile's trajectory. Iran first tested the Emad on October 11, 2015. [17]

Intermediate-Range Ballistic Missiles (IRBMs) Intermediate-Range Ballistic Missiles (IRBM) are classified as having a range between 3,000 and 5,000 km. Currently Iran has no operational IRBMs. However in 2005, Iran acquired an IRBM from North Korea. This North Korean IRBM, called the Musudan, has a range of between 2,500 and 4,000 km and a payload capacity of 1,200 kg. Despite acquiring Musudan technology, there is little evidence suggesting that Iran possesses an operational IRBM. [18] If Iran acquires an IRBM, it could strike targets in Central Europe and Asia.

Intercontinental-Range Ballistic Missiles (ICBMs) Iran's indigenous rocket motor research and development coupled with a growing space program indicate that the Islamic Republic is moving closer to developing an ICBM. Since 2008, Iran has been developing and testing rocket motor technology and multi-stage boosters that could be modified to construct a ballistic missile with intercontinental-range. Currently, Iran possesses two Space Launch Vehicles (SLV): the Safir and the Simorgh. The Safir is a two-stage solid-fueled SLV that Iran used to put satellites into orbit in February 2009, June 2011, and February 2012. [19] The Simorgh is a multi-stage liquid-fueled SLV that was designed to launch heavier payloads into orbit, but has not been used for a satellite launch. While neither of these SLVs have the payload capacity to deliver a military payload, reports estimate that the Simorgh SLV could be modified and weaponized in a few years. [20]

Iranian Safir rocket designed to carry a satellite

Cruise Missiles Iran possesses land-attack, anti-ship, and air-launched cruise missiles, many of which were acquired from other nations. Most of Iran's cruise missiles are purposed for anti-ship operations to supplement the nation's anti-access area denial strategy in the Persian Gulf, Straits of Hormuz, and Gulf of Oman. [21] Iran's anti-ship cruise missiles include the C-802, Noor, Ra'ad, and Qader. The C-802 was imported from China, and both the Noor and Qader cruise missiles are based on its design. The Noor has a range of 120 km, the Qader has a range of 200 km, and the Ra'ad has a range of 360 km. Some reports speculate that Iran has acquired long-range nuclear-capable cruise missiles—such as the Kh-55 from Russia and the HY-4 from China—in the 1990s and early 2000s. However, little evidence suggests that Iran is actively developing the capability to produce long-range cruise missiles. [22]

Section 2 - U.S. Missile Defense Systems

Standard Missile-3 (SM-3) Block 1B guided missile is launched from the USS Lake Erie, and successfully intercepted a medium-range ballistic missile target in October of 2013.

Photo: Missile Defense Agency

Aegis BMD Ships

Photo: Missile Defense Agency

Facts	
Mobility	Ship-based and highly mobile
Targets	Short-, medium-, and intermediate-range ballistic missiles
Role	Sea-based variant of the Aegis BMD designed to provide both regional and homeland missile defense and surveillance
Status	**33 Aegis BMD-capable vessels** deployed in U.S. fleets in the Pacific and Atlantic
Prime Contractor	Lockheed Martin
Approximate Cost	$2 Billion per ship

Overview

Aegis Ballistic Missile Defense (BMD) ships are the sea-based component of the Missile Defense Agency's Ballistic Missile Defense System (BMDS). Aegis BMD builds upon the Aegis Weapon System, Standard Missile, and Navy and joint forces' Command, Control and Communication systems. In total, there are 85 U.S. Navy vessels equipped with the Aegis Combat System, 33 of which have been modified for the role of BMD. The U.S. deploys Aegis BMD to provide both regional and homeland missile defense. In recognition of its scalability, Aegis BMD/SM-3 system is a keystone of the European Phased Adaptive Approach (EPAA).

The sea-based component of Aegis BMD employs Aegis-equipped cruisers and destroyers to intercept short-, medium-, and intermediate-range ballistic missiles in the midcourse and terminal phases of flight using hit-to-kill technology. Aegis vessels are also able to identify, track, and intercept low-flying cruise missiles. In addition to shorter range threats, Aegis BMD is employed to identify and track long-range ballistic missiles that—once identified—can subsequently be engaged by the Ground-based Midcourse Defense (GMD) system. Components of Aegis BMD include AN/SPY-1 radar, MK 41 Vertical Launching System, Command and Decision System, Global Command and Control System, Aegis Display System, and SM-2, SM-3, and SM-6 interceptors. [1] Future capabilities of Aegis BMD include engagement of longer-range ballistic missiles, improving existing early intercept capability, enhancing terminal capability against short- and medium-range ballistic missiles, increased number of ships and missiles, and more maritime ally involvement.

An SM-3 Block IB interceptor is launched from an Aegis BMD-capable cruiser—the USS Lake Erie (CG-70)—during a test in the mid-Pacific

Software Aegis BMD systems are programmed with highly sophisticated software to help identify, track, target, and intercept missile threats. This advanced software has contributed to a very successful test record—85% intercept success rate—and has established Aegis BMD as one of the most successful missile defense systems employed by the United States. Over time, Aegis BMD software has been incrementally modernized and improved upon. Version 3.6 is the earliest form of Aegis BMD software that is still employed, and is used by approximately 17 deployed Aegis vessels. Aegis BMD 3.6 configuration allows for Long Range Surveillance and Track (LRS&T) of ICBMs and intercept—using SM-3 Block IA interceptors—of short- to intermediate-range ballistic missiles in the midcourse and terminal phases. Aegis BMD 4.0 is the second generation of Aegis BMD software and—coupled with the SM-3 Block IB—allows for the engagement of increasingly longer range and more sophisticated ballistic missiles. There are currently nine deployed Aegis BMD vessels equipped with the 4.0 software.

Aegis BMD 5.0 is the most modern software upgrade—currently used by two deployed Aegis vessels—and increases the sea-based BMD force structure. The capability of Aegis BMD 5.0 was improved significantly by software upgrade Baseline 9, which allows Aegis vessels to engage cruise and ballistic missiles simultaneously. Baseline 9 was first tested in November 2014, when the guided-missile destroyer USS John Paul Jones (DDG 53) successfully intercepted a short-range ballistic missile and two cruise missiles. Four deployed Aegis BMD vessels are equipped with upgraded Aegis 5.0 Baseline 9 software. Aegis BMD 5.1, which is currently in development, will integrate the SM-3 Block IIA interceptor into the combat system to defeat longer-range ballistic missiles and allow the capability to engage on remote.

Regional Defense-Aegis BMD Engagement Capability Aegis BMD defeats short- to intermediate-range, unitary and separating, midcourse-phase, ballistic missile threats with the Standard Missile-3 (SM-3), as well as short-range ballistic missiles in the terminal phase with the SM-2 and SM-6. Fleet warships conduct flight tests for Aegis BMD and each test increases the operational realism and complexity of targets and scenarios. Aegis BMD-capable vessels are deployed to Europe, Asia, and the Middle East to provide regional missile defense. In Europe, the sea-based Aegis BMD and the land-based Aegis Ashore provide regional missile defense as established by the EPAA. Phase I of the EPAA called for deployment of Aegis BMD ships and land-based radar to Europe by the end of 2011. The first phase mandated that four Aegis ships be anchored in Rota, Spain. From there, these vessels deploy throughout the Mediterranean and Persian Gulf to protect southern Europe from ballistic missile attacks coming out of the Middle East. Phase II (2015) and III (2018) of the EPAA mandate interceptor improvements for Aegis-capable ships in Europe and the development of Aegis Ashore sites in Romania and Poland.

Homeland Defense-Aegis BMD Long Range Surveillance and Track Aegis BMD ships patrol, detect, and track ballistic missiles of all ranges – including intercontinental-range ballistic missiles—and report tracking data to the missile defense system. This capability shares tracking data to cue other missile defense sensors and provides fire control data to Ground-based Midcourse Defense (GMD) interceptors located at Fort Greely, Alaska and Vandenberg Air Force Base, California. Tracking data is also provided to other elements of the BMDS, including land-based firing units—Terminal High Altitude Area Defense and Patriot (PAC-3)—and other Aegis BMD ships.


Photo: Missile Defense Agency

USS John Paul Jones successfully engaging target using an SM-6 Dual I missile

Deployment As of June 2015, there are 33 Aegis BMD equipped ships (5 cruisers [CGs] and 28 destroyers [DDGs]) in the U.S. Navy. Of the 33 ships, 16 are assigned to the Pacific Fleet and 17 to the Atlantic Fleet. In response to the increasing demand for Aegis BMD capability from the Combatant Commanders, MDA and the Navy are working together to increase the number of Aegis BMD capable ships. Such efforts consist of upgrading Aegis DDGs to become BMD capable, incorporating Aegis BMD into the Aegis Modernization Program, and new construction of Aegis BMD DDGs. Under the EPAA, Aegis BMD vessels have been deployed to Europe, the Mediterranean, and the Persian Gulf since 2011. [2]

PACIFIC

Hull Number	Name	Version	Homeport
CG-70	Lake Erie	4.0	San Diego, CA
DDG-73	Decatur	4.0	San Diego, CA
DDG-65	Benfold	5.0 (Baseline 9)	Yokosuka, Japan
DDG-76	Higgins	3.6	San Diego, CA
DDG-59	Russell	3.6	San Diego, CA
DDG-69	Milius	3.6	San Diego, CA
CG-73	Port Royal	3.6	Pearl Harbor, HI
DDG-53	John Paul Jones	5.0 (Baseline 9)	Pearl Harbor, HI
DDG-77	O'Kane	3.6	Pearl Harbor, HI
DDG-60	Paul Hamilton	3.6	Pearl Harbor, HI
DDG-70	Hopper	3.6	Pearl Harbor, HI
CG-67	Shiloh	4.0	Yokosuka, Japan
DDG-63	Stethem	3.6	Yokosuka, Japan
DDG-54	Curtis Wilbur	4.0	Yokosuka, Japan
DDG-56	John S. McCain	4.0	Yokosuka, Japan
DDG-62	Fitzgerald	3.6	Yokosuka, Japan


Photo: U.S. Navy

Aegis Arleigh Burke-class destroyer the USS Donald Cook (DDG-75) arrives in Rota, Spain in 2014

Timeline

December 2015: Japan's Ministry of Defense (MOD) Acquisition, Technology and Logistics Agency (ATLA), and the MDA—in cooperation with the U.S. Navy—successfully conducted an SM-3 Block IIA flight Test from Point Mugu Sea Range, San Nicolas Island, California. The missile successfully demonstrated flyout through kinetic warhead ejection. No intercept was planned and no target missile was launched.

November 2015: The MDA, BMDS Operational Test Agency, Joint Functional Component Command for Integrated Missile Defense, U.S. European Command, and the U.S. Pacific Command conducted a complex operational flight test of the Ballistic Missile Defense System, demonstrating a layered defense architecture. The test stressed the ability of Aegis BMD and THAAD weapon systems to negate two ballistic missile threats while Aegis BMD simultaneously conducted an anti-air warfare operation.

October 2015: The U.S. Navy and eight other countries successfully conducted a detect-to-engage integrated air and missile defense exercise in the North Sea, during which the coalition simultaneously intercepted a ballistic missile in space and an anti-ship cruise missile target. This was the first missile defense test of its kind in Europe.

August 2015: The MDA, U.S. Pacific Command, and U.S. Navy successfully conducted a series of four flight test events at Kauai, Hawaii, demonstrating successful intercepts of short-range ballistic missiles and cruise missiles with the SM-6 Dual I and SM-2 Block IV interceptors. This was the first live fire event of the SM-6 Dual I missile.

June 2015: The U.S. and Japan announced the successful completion of a SM-3 Block IIA flight test from the Point Mugu Sea Range, San Nicolas Island, California. This was the first flight test of the SM-3 Block IIA, which is an interceptor variant designed to intercept medium- and intermediate-range ballistic missiles. Deployment of the SM-3 Block IIA is scheduled to begin in 2018.

July 2013: FTG-07 used Aegis BMD to identify and track a ballistic missile target that was intercepted by the GMD system. The Ground-based Interceptor was fired based on tracking data supplied by the USS LAKE ERIE (CG 70), the first use of an Aegis BMD ship as a launch-on-sensor in a Ground-based Midcourse Defense test. [3]

May 2012: Flight Test Mission 16 Event 2a was the first successful live fire intercept test of the second generation Aegis BMD Weapon System, BMD 4.0.1, and the SM-3 Block IB missile. In May 2012, the USS LAKE ERIE (CG 70) successfully intercepted a short-range ballistic missile target over the Pacific Ocean. Aegis BMD 4.0.1 and the SM-3 Block IB missile enabled the engagement of increasingly longer range and more sophisticated ballistic missiles. This was Aegis BMD's 22nd successful intercept out of 27 missile firings against various targets. [4]

ATLANTIC			
Hull Number	**Name**	**Version**	**Homeport**
CG-72	Vella Gulf	3.6	Norfolk, VA
CG-61	Monterey	3.6	Norfolk, VA
DDG-61	Ramage	3.6	Norfolk, VA
DDG-55	Stout	3.6	Norfolk, VA
DDG-58	Laboon	3.6	Norfolk, VA
DDG-72	Mahan	3.6	Norfolk, VA
DDG-67	Cole	4.0	Norfolk, VA
DDG-74	Mcfaul	4.0	Norfolk, VA
DDG-66	Gonzalez	4.0	Norfolk, VA
DDG-52	Barry	5.0 (Baseline 9)	Norfolk, VA
DDG-51	Arleigh Burke	5.0 (Baseline 9)	Norfolk, VA
DDG-57	Mitscher	3.6	Norfolk, VA
DDG-68	The Sullivans	3.6	Mayport, FL
DDG-71	Ross	3.6	Rota, Spain
DDG-64	Carney	4.0	Rota, Spain
DDG-75	Donald Cook	4.0	Rota, Spain
DDG-78	Porter	4.0	Rota, Spain

Strategic Implications

Europe Iran's developing ballistic missile program poses a threat to the European allies of the United States. To counter this emerging threat, the Obama Administration announced the EPAA, which called for an improved missile defense capability in Europe to counter any short- to intermediate-range ballistic missiles coming from the Middle East. The EPAA mandates the deployment of sea- and land-based Aegis BMD systems to protect Europe from a ballistic missile attack and assures our European allies of an increasingly important U.S. commitment to their security.

Asia The nuclear and ballistic missile capabilities of North Korea pose a threat to the United States and its allies in the Asia-Pacific region. To ensure that the security concerns of the United States and its allies are met, the U.S. Navy has deployed six Aegis-capable vessels to Japan and five to Hawaii, with an additional five in San Diego. Adding to the Pacific missile defense infrastructure are Japan's four Aegis BMD-capable Kongo Class Destroyers. These Aegis BMD vessels deployed by the United States and Japan not only defend against a potential ballistic missile attack from North Korea, but also deter the isolationist state from launching an attack against the U.S. and its allies. In the future, the United States hopes to enhance missile defense and deterrence in Asia by providing Aegis BMD technology to other U.S. allies in the Asia-Pacific region.

October 2011: The U.S., Spain, and NATO jointly announced that the U.S. would forward-deploy four Aegis-capable ships to Rota, Spain as part of the EPAA. These Aegis ships deploy throughout the Mediterranean to protect southern Europe against short- and medium-range ballistic missiles coming out of the Middle East.

April 2011: The MDA, U.S. Navy, and U.S. Army conducted a successful intercept of an intermediate-range ballistic missile using an SM-3 Block IA interceptor over the Pacific Ocean. Aegis BMD launched an SM-3 Block IA missile using tracking data from the AN/TPY-2 radar that was passed through the Command and Control Battle Management and Communication system to intercept an IRBM target. This test demonstrated the EPAA Phase 1 capability. This firing was the first Launch on Remote (LOR) Aegis BMD engagement and intercept of an IRBM. The firing was also outside the original design specifications for the SM-3 Block IA missile. [5]

March 2011: During Flight Test Mission 16, Event 1, the USS LAKE ERIE successfully tracked a ballistic missile target. In addition to the BMD mission, the LAKE ERIE also validated the ship's Anti-Air Warfare (AAW) capability by destroying an incoming anti-ship cruise missile target with an SM-2 Block III missile in a live firing exercise. This was the first event in which a ship used BMD 4.0.1 Weapon System to engage an AAW threat. [6]

October 2009: During FTX-06 Events 1 through 4, the guided missile Aegis cruiser USS LAKE ERIE (CG 70), upgraded with the BMD 4.0.1 Weapon System, successfully detected, tracked, and conducted simulated SM-3 Block IB engagements against a variety of different ballistic missile targets during a series of tracking exercises. The targets ranged from simple separating medium-range missiles to sophisticated, separating short-range missiles designed to confuse missile defense systems. All test objectives were met. Also, Japan Flight Test Mission (JFTM) 3 took place, during which the USS LAKE ERIE tracked separating ballistic missile targets with the second generation Aegis BMD Weapon System, BMD 4.0.1. In October 2010, JFTM 4 was carried out and conducted in a test similar to JFTM 3. [7]

September 2009: President Obama announced the EPAA, canceling a Bush Administration plan to place a third Ground-based Midcourse Defense (GMD) system in Poland. EPAA focuses on short- to intermediate-range threats originating from the Middle East and called for sea- and land-based Aegis BMD systems to be deployed incrementally throughout Europe from 2011 to 2018.

February 2008: A BMD-capable Aegis cruiser deployed northwest of Hawaii shot down an inoperable U.S. surveillance satellite that was in a deteriorating orbit. [8]

December 2007: In a flight test, a BMD-capable Japanese Aegis destroyer used an SM-3 Block IA interceptor to successfully intercept a ballistic missile target off the coast of Hawaii. This was the first time that a non-U.S. ship intercepted a ballistic missile using the Aegis BMD system.

2005: In 2005, Aegis BMD's role evolved to include an engagement capability. Aegis BMD ships armed with the SM-3 Block IA were capable of intercepting short- to intermediate-range ballistic missiles in the midcourse phase of flight. In 2006, Aegis BMD engagement capabilities were expanded to include terminal intercept capability.

The USS John Paul Jones, positioned west of Hawaii, detected, tracked, and launched a SM-6 Dual I missile, resulting in a third successful target intercept.

Photo: Missile Defense Agency

Standard Missile-2

Facts	
Mobility	Sea-based; employed by cruisers (CGN-type ships), destroyers (DDG-type ships) and Aegis CG-class ships
Targets	cruise missiles; aircraft; short- to intermediate-range ballistic missiles
Role	Approx. 74-166 km (medium range), Approx. 120-185 km (extended range); Surface-to-air missile; area theater ballistic missile defense; limited capability against surface targets
Prime Contractor	Raytheon

Overview

The Standard Missile-2 (SM-2) is a fleet-area air defense weapon that provides anti-air warfare and limited anti-surface warfare capability against advanced anti-ship missiles and aircraft. With a range of 90 nautical miles and a maximum altitude of 65,000 feet, the SM-2 is an integral part of the layered defense that protects naval assets, giving warfighters greater operational flexibility.

The SM-2 is a solid-fueled, tail-controlled, surface-to-air missile fired by surface ships. Designed to counter high-speed, high-altitude anti-ship cruise missiles (ASCMs) in an advanced electronic countermeasures (ECM) environment, its primary mode of target engagement uses mid-course guidance with radar illumination of the target by the ship for missile homing during the terminal phase. The SM-2 can also be used against surface targets.

The currently deployed SM-2 is derived from the SM-1 (RIM-GGB), which is still in the fleet. The SM-2 employs an electronic countermeasures-resistant monopulse receiver for semi-active radar terminal guidance and inertial midcourse guidance capable of receiving midcourse command updates from the shipboard fire control system. The SM-2 is launched from the Mk 41 Vertical Launching System (VLS) and the Mk 26 Guided Missile Launching System (GMLS). To counter expanding threat capabilities, the SM-2 continues to evolve and improve in advanced high and low-altitude threat interception. Specifically, the SM-2 is being improved to counter electronic countermeasures (ECM) through modular changes to the missile sections.

The Standard Missile was produced in two major types, the SM-1 MR/SM-2 (SM-2MR) and the SM-2. The SM-1 MR/SM-2 is a medium range surface-to-air missile (i.e. SM-2 Block II, III, IIIA, and IIIB), while the SM-2 is categorized as extended range (i.e. SM-2 Block IV and IVA), allowing it to provide Area Theater Ballistic Missile Defense (TBMD) along with fleet and extended area air defense.

SM-2 is one of the most reliable capabilities in the Navy's inventory and provides for the critical lower-tier of the layered missile defense infrastructure. Used against missiles, aircraft, and ships, it first came into the fleet more than a decade ago, replacing the Terrier and Tartar missiles on more than 100 Navy ships. The SM-2 (MR) is a medium-range defense weapon employed by Ticonderoga class Aegis cruisers, Arleigh Burke-class Aegis destroyers, California and Virginia class nuclear cruisers, and Kidd class destroyers with New Threat Upgrade (NTU) conversions. Oliver Hazard Perry-class frigates use the SM-1 MR. SM-2 Blocks II through IV provide protection against aircraft, anti-ship missiles, and ground targets.

The SM-2 has proven itself as a valuable anti-air and TBMD missile, even demonstrating limited ability to strike surface targets. As a result, many U.S. allies such as Australia, Canada, Germany, Japan, the Republic of Korea, the Netherlands, Spain, and Taiwan have adopted the SM-2.

SM-2 Variants

- ***SM-2 Block II*** This variant of the SM-2—along with the SM-2 Block III, IIIA, and IIIB—is a medium range missile that can be fired from Aegis rail launchers, Aegis vertical launch systems, and Tartar rail launchers. Improving on the SM-1, the SM-2 Block II has an improved fuse and focused-blast fragment warhead to provide better kill probability against smaller, harder targets and enhanced propulsion to allow for higher velocities and maneuverability. Block II also includes a signal processor that provides less vulnerability to ECM.

Photo: Raytheon

An SM-2 is launched vertically from a U.S. Navy vessel

- ***SM-2 Block III*** This medium range variant of the SM-2 has improved capability against low altitude targets.

- ***SM-2 Block IIIA*** The medium range Block IIIA increases SM-2 capabilities at even lower altitudes than the Block III and includes a new warhead that enhances the velocity of warhead fragments moving in the direction of the target.

- ***SM-2 Block IIIB*** The medium range SM-2 Block IIIB incorporates an infrared guidance mode capability developed with the radio frequency semi-active guidance system of the Block IIIA. Called the Missile Homing Improvement Program (MHIP), the dual radio frequency and infrared guidance mode is being incorporated to counter specific proliferating electronic warfare systems in existing aircraft and anti-ship cruise missiles.

- ***SM-2 Block IV*** This variant, along with the SM-2 Block IVA, is an extended range missile that is vertically launched and has a longer range than the Block II, III, IIIA, and IIIB variants. The Block IV has improved cross-range and higher altitude capability for Aegis vertical launch ships and improved performance against low targets and complex ECM. This improved performance is the result of a thrust-vector controlled booster, a more robust airframe, and guidance and control modifications. Significantly, the SM-2 Block IV is the Navy's first missile capable of TBMD, having the ability to intercept theater ballistic missiles in their terminal phase of flight. The purpose of the SM-2 Block IV is to enhance U.S. warfare capability by allowing Aegis ships to provide TBMD for ships at sea and ground forces ashore, while also retaining its anti-air function.

- ***SM-2 Block IVA (cancelled)*** To counter theater ballistic missiles, the Block IVA was designed to employ a dual-mode radio frequency/infrared sensor, an upgraded ordnance package, and autopilot control enhancements. The program was canceled in 2001 because it was more than 50 percent over budget and two years behind schedule. However, Block IVA improvements to the SM-2 missile design inspired development of the longer-range Standard Missile-3.

Current developments

Starting in 2015, the new Standard Missile-6 (SM-6)—designed to provide fleet air defense against fixed- and rotary-wing aircraft, unmanned aerial vehicles, and land-attack anti-ship cruise missiles in flight—is scheduled to phase out the SM-2 Block IV missile. The SM-6 employs the Standard Missile airframe and propulsion elements, while incorporating the advanced signal processing and guidance control capabilities of the Advanced Medium-Range Air-to-Air Missile (AMRAAM).

Standard Missile-3

Photo: Raytheon

Facts	
Mobility	Sea- and land-based
Targets	Short, intermediate-range ballistic missiles; satellite intercept capable
Role	Approx. 700 km (Block IA and IB), Approx. 1,500 km (Block IIA); area missile defense, eventually all phases of missile defense
Prime Contractor	Raytheon

Overview

The Standard Missile-3 (SM-3) is a derivative of the RIM-156 Standard SM-2 Block IV missile, and is the interceptor component of the U.S. Navy theater ballistic missile defense system, called Navy Theater Wide – Theater Ballistic Missile Defense (NTW-TBMD). It is an upper-tier (exo-atmospheric) ballistic missile defense weapon designed to intercept short- to intermediate-range ballistic missiles in the midcourse and terminal phases of flight. The SM-3 was originally planned to complement the lower-tier SM-2 Block IVA until the latter was canceled in December 2001. However, modern Aegis software has allowed the SM-3 to work in cooperation with lower-tier SM-2 and SM-6 air defense missiles.

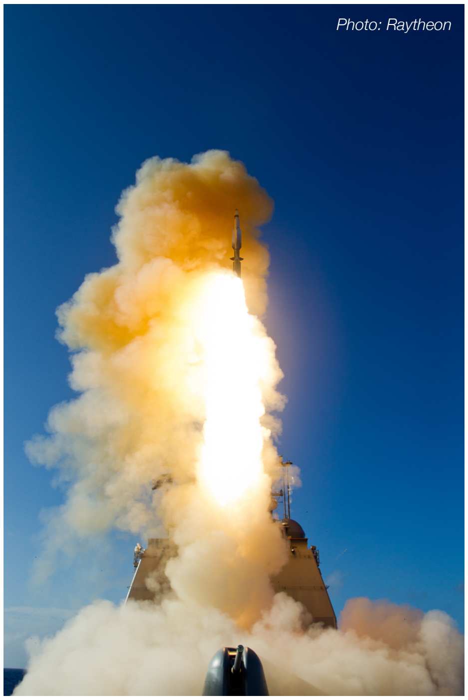


Photo: Raytheon

An SM-3 Block IB is launched from a U.S. Navy vessel during an intercept test

The SM-3 missile, designated RIM-161A, uses the basic SM-2 Block IVA airframe and propulsion, and adds a third stage rocket motor (a.k.a. Advanced Solid Axial Stage, ASAS, made by Alliant Techsystems), a GPS/INS guidance section (a.k.a. GAINS, GPS-Aided Inertial Navigation System), and a LEAP (Lightweight Exo-Atmospheric Projectile) kinetic warhead (a non-explosive hit-to-kill warhead). The SM-3 interceptor replaced the SM-2's explosive warhead and radar seeker with an additional solid-fueled third-stage motor and infrared homing kinetic kill vehicle, otherwise known as a LEAP.

The LEAP uses a Forward Looking Infrared (FLIR) sensor to locate its target, and was tested in 4-flight series called Terrier/LEAP from 1992 to 1995. These tests used modified Terrier and Standard Missile-2 missiles. Two intercepts were attempted during these tests, but the LEAP failed to hit the target in both cases. The first flight-test of an RIM-161A SM-3 missile occurred in September 1999, and the third test (in January 2001) demonstrated successful missile flight and control up to fourth stage (i.e. kinetic warhead) separation. In January 2002, the first all-up test of an SM-3 succeeded in intercepting an Aries ballistic target missile. SM-3 has successfully achieved 28 out of 36 intercepts during tests including a satellite shoot down in February 2008.

SM-3 Variants

- *SM-3 Block I* This SM-3 variant was a limited production version that provided the first operational Aegis BMD intercept capability in 2005 when the USS Lake Erie conducted an intercept test. Only eleven were built, and four of these were used during tests.
- *SM-3 Block IA* The Block IA variant of the SM-3 is designed to intercept short- and intermediate- range ballistic missiles, incorporating rocket motor upgrades and computer program modifications to improve sensor performance and missile guidance and control. The Block IA is the first production version of the SM-3, being deployed on the USS Shiloh in 2006 as part of the Aegis BMD 3.6 deployment. The SM-3 Block IA interceptor is employed by Aegis BMD 3.6 vessels.
- *SM-3 Block IB* This SM-3 variant became operational in 2014, and has an enhanced two-color infrared seeker and upgraded steering and propulsion capability that uses short bursts of precision propulsion to direct the missile towards incoming targets. The new two-color sensor provides the capability to sense infrared information in two distinct wavebands, improving the identification of multiple objects. A throttleable Divert Altitude Control System (TDACS) provides the SM-3 IB with more post-launch maneuverability than its predecessors. Overall, the Block IB variant is capable of engaging ballistic missile targets at longer range with increased threat discrimination and is carried by Aegis BMD 4.0 vessels.
- *SM-3 Block IIA* This SM-3 variant is being jointly developed and tested by the United States and Japan, and is expected to be deployed operationally and carried by sea- and land-based Aegis BMD 5.1 systems in 2018. The interceptor will have new second and third rocket stages, allowing it to travel at much higher speeds than Block I missiles. Although the Block IIA is designed to counter short- to intermediate- range threats, the missile's enhanced speed provides it with limited capability against Intercontinental-range ballistic missiles as well. The Block IIA will have a new kill vehicle with heightened seeker sensitivity, increased divert capability, and longer operating time once released from its booster rocket. Although it is still in the testing phase, Phase III of the European Phased Adaptive Approach calls for employment of the SM-3 Block IIA in Europe by 2018.
- *SM-3 Block IIB (cancelled)* Prior to its cancellation in 2013, the SM-3 Block IIB was designed specifically for the Fourth Phase of the European Phased Adaptive Approach, which was scheduled to be carried out sometime after 2020. This missile variant would have had an even higher speed booster than the Block IIA and would be equipped with a lighter kill vehicle, making it ideal for intercepting faster moving and longer range ICBMs.

The European Phased Adaptive Approach (EPAA)

Aegis BMD and the SM-3 make up the foundation of the EPAA. Each phase of the EPAA calls for the deployment of upgraded SM-3 variants to counter the improving ballistic missile capabilities of Iran. In March 2011, Phase I of the EPAA mandated deployment of 113 SM-3 Block IA interceptors and 16 SM-3 Block IB interceptors to Aegis BMD ships in Europe.

In 2015, Phase II called for 100 SM-3 Block IB interceptors to be deployed to Europe alongside the new Aegis Ashore site in Romania. The new land-based variant—Aegis Ashore—is configured with Aegis BMD 5.0 and SM-3 IB interceptors. Aegis BMD 5.0 does not add new functionality, but is designed to integrate Aegis BMD 4.0.1 with the Navy's open architecture system, enabling any Aegis ship to perform the BMD mission.

Scheduled for 2018, the third phase of the EPAA mandates the deployment of 19 new SM-3 Block IIA interceptors alongside the development of another Aegis Ashore site Poland. Phase IV of the EPAA originally called for the deployment of SM-3 Block IIB interceptors, which are capable of intercepting ICBMs coming out of Iran. However the fourth phase of the EPAA was ultimately cancelled and development of the SM-3 Block IIBt was halted.

Current Developments

The Department of Defense shifted strategies for the defense of Europe from one that relied on Ground-based Midcourse Defense interceptors in Poland, to implementing the new European Phased Adaptive Approach (EPAA), in which Aegis BMD became the centerpiece. The currently deployed systems for Phase I and II of the EPAA are Aegis BMD 3.6.1, 4.0.1, and 5.0 with SM-3 Block IA and IB interceptors. Phase III of the EPAA calls for the development, testing, and deployment of new SM-3 Block IIA interceptors and Aegis BMD 5.1 systems to Europe by 2018.

To meet the mandates set by Phase III of the EPAA, the U.S. Navy, in cooperation with Japan, is currently developing and testing the SM-3 Block IIA interceptor. This interceptor has a greater range and higher velocity to intercept fast-moving intermediate-range ballistic missiles more effectively. In June 2015, the Block IIA was first flight tested and the interceptor successfully demonstrated flyout through nosecone deployment and third stage flight. In December of that year, the SM-3 Block IIA again underwent a flight test and successfully demonstrated flyout through kinetic warhead ejection. The SM-3 Block IIA will continue being tested until its scheduled deployment in 2018, at which time it is expected that Aegis BMD 5.1 will employ the Block IIA interceptors on both ships and at the Aegis Ashore site in Poland.

Standard Missile-6

Photo: Raytheon

Facts	
Mobility	Sea-based; deployed on Aegis cruisers and destroyers
Targets	cruise missiles; aircraft; unmanned aerial vehicles; Short- to intermediate-range ballistic missiles in the terminal phase
Role	Approx. 240-370 km; Surface-to-air missile; theater ballistic missile defense; capable against surface targets
Prime Contractor	Raytheon

Overview

The Standard Missile-6 (SM-6)—also known as the RIM-174—retains the Standard Missile airframe and propulsion elements and incorporates the advanced signal processing and guidance control capabilities of the Advanced Medium-Range Air-to-Air Missile (AMRAAM). It is the latest addition to the Standard Missile family of fleet air defense missiles and provides Joint Force and Strike Force Commanders fleet air defense against fixed- and rotary-wing aircraft, unmanned aerial vehicles, and land-attack anti-ship cruise missiles in flight. The cost to obtain and maintain the SM-6 is also comparatively low, allowing more defensive interceptors to be employed in the battlespace, enhancing the U.S. Navy's fleet air defense capability against numerous airborne threats.

Photo: Raytheon

An SM-6 is launched from the USS John Paul Jones (DDG 53)

The SM-6 is vital to the U.S. Navy's Naval Integrated Fire Control—Counter Air (NIFC-CA) and provides surface vessels with increased battlespace protection against over-the-horizon anti-warfare threats. Retaining the Standard Missile legacy, the SM-6's operational modes include semi-active homing and active homing to provide highly accurate target engagement. The SM-6 is vertically launched from a MK 41 VLS canister and is compatible with existing Aegis cruisers and destroyers. The missile interceptor receives midcourse flight control from the Aegis Combat System via the ship's radar. Terminal flight control is autonomous via the missile's active seeker or supported by the Aegis Combat System via the ship's illuminator.

Dual-Mission Capability

The SM-6 has dual-mission capability, meaning it can defend against both cruise and ballistic missile threats. This capability is called SM-6 Dual I and is designed to intercept short-range theater ballistic missiles in the terminal phase of their trajectory. SM-6 Dual I adds a critical layer to the ballistic missile defense network of the U.S. Navy. In 2015, the SM-6 Dual I was tested three times and successfully demonstrated its Sea-Based Terminal (SBT) role against ballistic missiles as well as its air warfare capability.

Similar to its predecessor, the SM-2, the SM-6 also has limited offensive capabilities, and, when equipped with GPS, can carry out strikes on land and sea targets at a range of 200 miles. This new anti-ship capability is aimed at countering the surface strike threat posed by Chinese naval vessels with long-range anti-ship cruise missiles and would force them to stand off at ranges more favorable to U.S. aircraft carriers.

SM-6 Variants

- *SM-6 Block I* The Block I has a Dual-Mode Seeker (Active and Semi-Active), a solid rocket booster, and dual thrust solid rocket motors. In 2013, the SM-6 Block I reached Initial Operating Capability when it was deployed aboard U.S. Aegis Destroyer USS Kidd (DDG-100). During a test intercept in June 2014, the SM-6 Block I—fired from the USS John Paul Jones (DDG 53)—conducted the longest surface-to-air engagement in naval history. In 2015, the Block I carried out two successful intercepts, both of which involved cruise missile targets that were conducting electronic attacks against either the SM-6 missile or the Aegis shipboard radar. In February 2016, two SM-6 Block I missiles successfully intercepted two cruise missile targets simultaneously.

- *SM-6 Block IA* This SM-6 configuration is designed to address hardware and software improvements and advanced threats. In November 2014, the Block IA successfully intercepted a subsonic cruise missile over land, marking the second successful flight test of the SM-6 variant.

- *SM-6 Dual I* The Dual I is designed to counter ballistic missiles in the terminal phase of their trajectory as well as cruise missiles and other air breathing threats. Dual I upgrades include a more powerful processor that runs a more sophisticated targeting software that allows the SM-6 Dual I to identify, track, and intercept targets descending from the upper atmosphere at high velocity. During an intercept test in July 2015, the SM-6 Dual I demonstrated its dual-mission capability when it successfully intercepted a short-range ballistic missile target, in addition to two different kinds of cruise missile targets.

Current Developments

In 2016, the Navy plans to demonstrate the maximum range of the Key Performance Parameter (KPP) during SM-6 follow-on operational test and evaluation and Aegis Baseline 9 operational testing as well as the launch availability KPP. The Pentagon's 2017 budget includes a $2.9 billion request for the SM-6, which Defense Department officials recently revealed will be gaining a supersonic anti-ship capability. This SM-6 upgrade was discussed by Secretary of Defense Ash Carter, who stated that, "We're modifying the SM-6 so that in addition to missile defense, it can also target enemy ships at sea at very long ranges." The initial deployment of the SM-6—called Increment 1—is scheduled to begin in 2016, to be followed by a subsequent deployment—called Increment 2—in 2018, at which time the SM-6 is expected to reach full operational status.


Photo: Raytheon

An SM-6 is launched from a U.S. Navy vessel

Aegis Ashore

Photo: Missile Defense Agency

Facts	
Mobility	Stationary with removable facilities for worldwide deployment
Targets	Short-, medium-, and intermediate-range ballistic missiles
Role	Land-based variant of the sea-based Aegis BMD system
Status	**1 Active site at Deveselu Military Base, Romania,** future site at Redzikowo, Poland and a test site in Kauai, Hawaii
Prime Contractor	Lockheed Martin
Approximate Cost	$1.6 billion for the Romanian and Polish sites

Photo: U.S. Army Corps of Engineers

Aegis Ashore site under construction in Romania

Overview

Aegis Ashore was first announced in 2009 as part of the European Phased Adaptive Approach (EPAA) and is the land-based variant of the sea-based Aegis Ballistic Missile Defense (BMD) system. Aegis Ashore shares components of the ship-based version including the Aegis AN/SPY-1 radar, Command, Control, and Communication systems, Computers and Intelligence (C4I) systems, MK-41 Vertical Launch Systems, computer processors, display systems, power supplies, and SM-3 interceptor missile variants. The system is designed to identify, track, and intercept short-, medium-, and intermediate-range ballistic missiles during their midcourse phase of flight. To keep pace with the evolving ballistic missile threat, Aegis Ashore facilities are also removable, allowing for mobility, adaptability, and worldwide deployment. [1] Currently, Aegis Ashore is operationally deployed in Romania, with a test facility in Kauai, Hawaii. The third phase of the EPAA calls for another site which is scheduled to be developed in Poland by 2018. [2] Future capabilities of Aegis Ashore will include engagement of longer range missiles, enhanced terminal capability against short- and medium-range ballistic missiles, early intercept, and engage-on-remote features. [3]

Strategic Implications

Europe The EPAA was designed to be a cost-effective method for the creation of a layered missile defense network in Europe that would protect U.S. partners, allies, and assets in the region from the growing Iranian ballistic missile threat. Although the U.S. has repeatedly insisted that the deployment of Aegis BMD systems in Europe are designed to counter short- to intermediate-range ballistic missile threats from the Middle East, Russia has objected to the layered missile defense network, saying that it undermines the credibility of its strategic deterrence. [4] Aegis systems in Europe are designed and positioned to defend against ballistic missiles coming from the Middle East and lack the technological capability to counter intercontinental-range threats coming out of Russia. While the missile defense network called for by the EPAA would be technically unable to negate or undermine Russia's strategic nuclear arsenal, Moscow remains concerned that the missile defense system in Europe will continue to expand and impede its ability to deter.

Asia Aegis Ashore has also influenced the strategic landscape of the Asia-Pacific region, specifically playing a role in countering the ballistic missile capabilities of North Korea. In early 2016, the U.S. began to consider operationalizing the Aegis Ashore Test Facility in Kauai, Hawaii in response to North Korea's improving nuclear and ballistic missile capabilities. The Aegis BMD facility in Kauai would add an additional layer of protection for the state of Hawaii and the U.S. homeland to counter North Korean ballistic missiles.

Aegis Ashore completes its first intercept flight test in December of 2015

Timeline

2018 (planned): The third phase of the EPAA calls for Aegis Ashore to be deployed in Poland by 2018. Phase III employs an upgraded modification of Aegis Ashore equipped with improved software and SM-3 interceptors to extend ballistic missile coverage to Northern Europe. To increase its range and effectiveness, the Aegis BMD site in Poland will utilize improved 5.1 software and, in addition to SM-3 Block IB interceptors, will be equipped with longer-range SM-3 Block IIA interceptors.

December 2015: In late 2015, the ground-based component of Aegis BMD was deployed at the Deveselu Military Base in Romania for Phase II of the EPAA. Equipped with SM-3 Block IB interceptors and Aegis BMD 5.0 software, the Aegis Ashore system in Romania is designated to provide ballistic missile coverage for Southern Europe.

June 2015: The Standard Missile-3 Block IIA was successfully flight tested for the first time. The SM-3 Block IIA, co-developed by the U.S. and Japan, will fulfill its mission on land as part of the Aegis Ashore system (EPAA Phase III in Poland) and at sea on Aegis ships, including the Japanese Kongo class ships. [5]

February 2015: The FY2016 MDA Budget request calls for $169 million in military construction for the Aegis Ashore site in Poland.

November 2014: The Missile Defense Agency successfully conducted a flight test (FTM-25) of Aegis BMD technology including components of Aegis Ashore. The system tracked and intercepted two cruise missiles and a short-range ballistic missile simultaneously. [6]

October 2014: The United States Navy held a Naval Support Facility Establishment Ceremony to install an American commander at the Deveselu facility in Romania. The ceremony was the first step in transitioning the base from a construction site to a site of operations.

May 2014: The first flight test of the Aegis Ashore system was successfully conducted at the Pacific Missile Range Facility (PMRF) in Kauai, Hawaii. Tests at the PMRF will ensure that the software and hardware architecture of the Aegis Ashore system in Romania is tested on a live-fire range.

September 2009: President Obama announced the EPAA, canceling a Bush Administration plan to place a third Ground-Based Midcourse (GMD) missile defense system in Poland.

In June of 2014, a long-range ground-based interceptor was launched from Vandenberg Air Force Base, California, and intercepted an intermediate-range ballistic missile target.

Photo: Missile Defense Agency

Ground-Based Midcourse Defense (GMD)

Photo: Missile Defense Agency

Facts	
Mobility	Non-mobile, ground-based
Targets	Long- and intermediate-range ballistic missiles
Role	Long-range, exo-atmospheric interceptor
Status	**30 interceptors** deployed to Fort Greely, Alaska (26) and Vandenburg Air Force Base, California (4) with plans to increase to 44 by 2017
Prime Contractors	Boeing (GBI), Raytheon (EKV), Orbital ATK (GBI booster), Northrop Grumman (C2BMC)
Approximate Cost	$70 million per interceptor

Photo: Missile Defense Agency

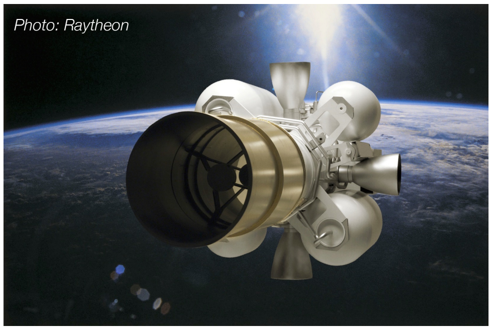
A GBI is lowered into its silo in Fort Greely, Alaska in 2004

Overview

The Ground-based Midcourse Defense (GMD) element of the Ballistic Missile Defense System provides the capability to engage and destroy limited intermediate- and long-range ballistic missile threats in space to protect the United States homeland. GMD employs integrated communications networks, fire control systems, globally deployed sensors, and Ground-based Interceptors (GBIs) that are capable of detecting, tracking and destroying ballistic missile threats. The Exo-atmospheric Kill Vehicle (EKV) is a sensor/ propulsion package that uses the kinetic energy from a direct hit to destroy the incoming target vehicle. [1]

In the late 1990s, North Korea demonstrated significant progress on its nuclear and ballistic missile program, particularly in its ability to strike the U.S. homeland. In response to the emerging North Korean threat, the United States announced its intention to withdraw from the 1972 Anti-Ballistic Missile Treaty (ABM), which prohibited the deployment of new ballistic missile defense capabilities. In its 2001 statement announcing its intention to withdraw from the ABM Treaty, the White House cited the shift in geostrategic challenges as the primary motivation for breaking the treaty saying “[the] threats we face today are far different from those of the Cold War.” [2] While Russia historically objected to the deployment of a national ballistic missile defense system in 2001, Russian President Vladimir Putin released a statement in response to the decision of the U.S. saying “the decision made by the President of the United States does not pose a threat to the national security of the Russian Federation.”[3] National Security Policy Directive 23, issued in December of 2002, directed the Department of Defense to deploy a set of missile defense capabilities for operational use by 2004. [4]

Homeland Defense GMD is currently the only system the U.S. deploys capable of protecting the homeland from intercontinental ballistic missile (ICBM) threats. GMD is designed to defend against limited ICBM threats from rogue nations such as North Korea and Iran, and is not designed to counter the strategic forces of nations that possess advanced ICBM capabilities such as Russia and China.



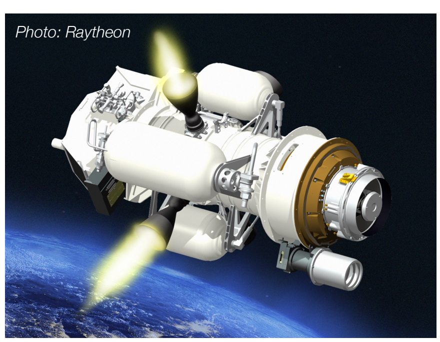
An artist's rendering of an Exoatmospheric Kill Vehicle (EKV)

International Cooperation Upgraded Early Warning Radars (UEWR), located in RAF Fylingdales, United Kingdom and Thule Air Base, Greenland, provide midcourse coverage for the BMDS to detect sea-launched or intercontinental ballistic missiles. These radars also provide ballistic missile tracking data, which commits the launch of interceptors and provides them with in flight updates on the target's location. [5]

In addition to early warning radars, early homeland missile defense plans also called for cooperation with European allies on the deployment of elements of the GMD system. In response to the development of the Iranian ballistic missile threat, President George W. Bush formally entered into negotiations with the governments of Poland and the Czech Republic in 2007 to host elements of the GMD system in their countries that would defend against intermediate to long range ballistic missiles originating from Iran. President Bush's plan called for up to 10 two-stage GBIs in Poland and an X-Band Radar in the Czech Republic. However, upon entering the White House in 2009, President Barack Obama cancelled the Bush Proposal and announced the European Phased Adaptive Approach (EPAA) in its place on September 17, 2009. While EPAA provides reliable theater defense against ballistic missiles up to the intermediate range, the plan lacks the homeland defense element of the Bush administration's proposal.

Deployment By the end of 2016, there will be a total of 37 GBI interceptors deployed to protect the homeland. This will include 33 GBIs in Fort Greely, Alaska and 4 deployed to Vandenberg Air Force Base, California. An additional 7 GBIs will be deployed to Fort Greely by the end of 2017 for a total of 44 interceptors.

Modernization Two key programs will contribute to the modernization of the GMD System, the Long Range Discrimination Radar (LRDR) and a next generation kill vehicle, the Redesigned Kill Vehicle (RKV). The LRDR, scheduled to begin defensive operations in 2020, will serve as a midcourse sensor to improve target discrimination capability for the BMDS to better address potential countermeasures and increase the capacity of the GBIs in Alaska and California. [6] The RKV, scheduled for initial deployment in 2020, will incorporate performance enhancements in target acquisition, discrimination, and survivability. The RKV will also feature on-demand communications that enable better use of off-board sensor data and provide improved situational awareness for the warfighter. The first flight test of the RKV is planned for 2018, and the first intercept test is planned for 2019. [7] Together, these enhancements will allow the system to lower the "shot doctrine", or the number of interceptors needed to successfully destroy an incoming warhead.



An artist's rendering of a Redesigned Kill Vehicle (RKV)

Timeline

January 2016: MDA, in cooperation with the U.S. Air Force 30th Space Wing, the Joint Functional Component Command for Integrated Missile Defense, and U.S. Northern Command, successfully conducted a non-intercept flight test of the Ground-based Midcourse Defense system.

June 2014: MDA successfully conducted a test in which a long-range GBI launched from Vandenberg Air Force Base, California, intercepted a threat-representative, intermediate-range ballistic missile target launched from the U.S. Army's Reagan Test Site on Kwajalein Atoll in the Republic of the Marshall Islands.

July 2013: MDA, U.S. Air Force 30th Space Wing, Joint Functional Component Command, Integrated Missile Defense (JFCC IMD) and U.S. Northern Command conducted an integrated exercise and flight test of the Ground-based Midcourse Defense system. Although a primary objective was the intercept of a long-range ballistic missile target, an intercept was not achieved.

March 2013: Secretary of Defense Chuck Hagel announced a plan to deploy an additional 14 GBIs to Alaska following North Korean provocations.

December 2010: MDA was unable to achieve a planned intercept of a ballistic missile target during a test over the Pacific Ocean. The Sea Based X-Band radar (SBX) and all sensors performed as planned. The GBI was launched and successfully deployed an Exoatmospheric Kill Vehicle (EKV).

January 2010: MDA conducted a flight test of the Ground-based Midcourse Defense System which failed to intercept its target.

December 2008: MDA successfully completed an exercise and flight test involving a successful intercept by a GBI missile. For this exercise, a threat-representative target missile was launched from Kodiak, Alaska at 3:04pm (EST). This long-range ballistic target was tracked by several land- and sea-based radars, which sent targeting information to the interceptor missile.

May 2008: The Multiple Kill Vehicle (MKV) program successfully demonstrated the engagement management algorithms for the Multiple Kill Vehicle-L carrier vehicle during a modeling and simulation exercise.

September 2007: MDA successfully completed an exercise and flight test involving a successful intercept by a GBI demonstrating the ability of the Upgraded Early Warning Radar to acquire, track and report on objects. The test also evaluated the performance of the interceptor missile's rocket motor system and exoatmospheric kill vehicle.

Transportable GBIs In the future, the operational flexibility of GMD might be increased with the application of transportable GBIs, which are self-contained mobile GMD systems that can be employed to counter emerging threats from any desirable location. Components of the transportable GMD system include a mobile tanking trailer, a Transportable Launch Support System (LSS), an In-Flight Interceptor Communication System (IFICS) Data Terminal (IDT), and a Transportable-Erector (TE) from which the GBI is launched. [8] To launch a transportable GBI, the mobile tanking trailer—carrying the TE and GBI—is parked and the GBI is erected minutes prior to takeoff. In coordination with the IFICS, IDT, and other radars and sensors, the transportable GBI is then launched from the TE and guided to its target like a silo-based GBI. Transportable GBIs can be readily moved to existing launch pads and maintained in readiness state. The TE and other launch-support and communication systems also provide a cheaper alternative to conventional GBI silos, and shorter manufacturing periods enable early deployment of mobile GBIs at Vandenberg Air Force Base, with and the potential to expand to new sites. [9]

February 2005: MDA was unable to complete a planned flight test after the interceptor missile did not launch from the Ronald Reagan Test Site, Republic of the Marshall Islands, in the central Pacific Ocean.

December 2004: The Missile Defense Agency (MDA) was unable to complete a planned flight test after the interceptor missile experienced an anomaly shortly before it was to be launched from the Ronald Reagan Test Site, Republic of the Marshall Islands, in the central Pacific Ocean.

July 2004: Missile Defense Agency emplaces First Interceptor at Fort Greely, Alaska.

Strategic Implications

North Korea is currently developing an increasingly sophisticated nuclear and ballistic missile capability. In December 2012 and February 2016, North Korea successfully placed satellite payloads into orbit via a long range rocket, the Unha-3, which Pyongyang maintains is intended only as a space launch vehicle (SLV). However, developing a SLV contributes heavily to North Korea's long-range ballistic missile development, since the two vehicles have many shared technologies. [10] In a 2012 military parade, the DPRK unveiled a new road-mobile ICBM, the KN-08. While the KN-08 has not yet been flight tested, the Department of Defense assesses that North Korea currently possesses at least 6 launchers for the ICBM. [11] With a range of over 3400 miles, these long-range missiles have the ability to reach a number of targets within the U.S. homeland. Iran has also carried out four satellite launches, with the most recent occurring in February of 2015. [12] The GMD system is capable of defending the entire United States from current long-range threats originating from North Korea. Modernization efforts for GMD will ensure that the system stays ahead of the developing North Korean threat.

The Missile Defense Agency conducted a successful flight test in Jan. 2016

Photo: Raytheon

Patriot

Facts	
Mobility	Ground-based, mobile
Targets	UAV, Cruise Missiles, Short-range Ballistic Missiles
Role	15km (PAC-3), 22km, interceptor
Status	**15 Battalions**, Interceptor sites all over the globe including in cooperative nations in Europe and the Middle East
Prime Contractors	Lockheed Martin, Raytheon
Approximate Cost	In FY12, the unit cost of an Enhanced Launcher Electronic System (ELES) was around $3.82 million


Photo: Raytheon

A PAC-3 AN/MPQ-53 C-band multifunction phased array radar system

Overview

The Patriot missile defense system is a ground-based, mobile missile defense interceptor deployed by the United States and many other nations. The Patriot system detects, tracks, and engages UAVs, cruise missiles, and short-range or tactical ballistic missiles. Patriot missile systems have been tested in combat operations in the Middle East during Desert Storm and Operation Iraqi Freedom and are deployed around the world.

The Patriot system consists of five major components: a radar set, engagement control station, missile launchers, Patriot missiles, and power plant truck. The radar set is made up of an AN/MPQ-53 C-band, multifunction phased array radar system that is remotely controlled by the MSQ-104 control station. The radar is able to detect and track more than 100 potential targets and has a range of over 100 km. [1] The AN/MSQ-104 engagement control station is the only manned part of a Patriot unit and is designed to communicate with the launching stations, other Patriot batteries and headquarters, and track and prioritize targets. The control station is typically manned by three operators who are responsible for the two consoles and a communications station with three radio relay terminals. [2] In order to power the radar set and engagement control system, each Patriot unit also has a power plant truck equipped with two 150-KW generators.

The missile launchers and Patriot missiles complete the Patriot system. Each missile launcher has four canisters and transports, aims, and fires the missiles.The missile launcher can be located separately from the radar and control station and can be ready to fire a missile in less than 9 seconds. [3] Once the missile launches it transmits data back to the radar station which tracks and helps guide the missile to its target. The Patriot missile has been upgraded since it was first deployed and variations include the PAC-2, PAC-3, GEM-T, and PAC-3 MSE missiles.

Regional Defense While Patriot missile defense systems are capable of operating independently to intercept short-range missiles and other airborne threats, they are primarily designed as a point defense. This means that they protect a specific asset or location, and are best deployed as part of a layered missile defense system since the missiles have a range of only about 15-22 km and the radar has a range of about 100 km. As part of a layered defense system, Patriot systems are able to work with other missile defense system such as THAAD to form a multi-tier, integrated, overlapping defense against missile threats in the terminal phase of flight.

International Cooperation Patriot missile defense systems have been purchased by more than 14 countries including 5 NATO allies and are deployed around the world. Countries with Patriot missile defense systems include NATO allies: Germany, Spain, Netherlands, Greece, and Poland (considering the Patriot system); countries in the Middle East: Israel, Egypt, Kuwait, Qatar, Saudi Arabia, and the United Arab Emirates; and countries in the Pacific: Taiwan, South Korea, and Japan.

Deployment The Patriot system is designed to provide air and missile defense capabilities at a tactical level in defense of U.S. deployed forces and allies. Numerous countries currently field Patriot missile defense systems around the world to protect civilian populations and deployed troops from the threat of cruise missiles, ballistic missiles, rockets, and aircraft. Patriot systems were combat tested during Operation Desert Storm, Operation Iraqi Freedom, and used as part of Israel's Iron Dome missile defense system.

Future Capabilities As of 2015, the latest Patriot missile, the Patriot PAC-3 Missile Segment Enhance (MSE), completed operational testing and has been approved for initial production. The PAC-3 MSE features a larger, dual pulse solid rocket motor, larger fins, and upgraded actuators and thermal batteries to accommodate increased performance and extend the range of the missile. The Patriot system is also undergoing further enhancements and upgrades including a new Gallium Nitride (GaN) Active Electronically Scanned Array (AESA) radar designed to increase detection range and provide 360 degree coverage, a new common command and control system to enable operation with partners and allies, and the ability to fire multiple missile types.

Strategic Implications

Middle East In the past several years, numerous countries have deployed Patriot systems to secure their borders and protect their troops from the threat of tactical ballistic missiles. Between January 2013 and the end of 2015, Turkey hosted five (still hosts one) NATO Patriot batteries to augment the country's missile defense capabilities against the threat of ballistic missiles from the conflict in Syria. Since 2012, these Patriot batteries have detected several hundred ballistic missile launches within Syria [4] and tracked their flight path making sure that they did not pose a threat to Turkish civilians or forces deployed along the border.

In addition to Turkey, the United Arab Emirates (UAE) and Saudi Arabia currently field Patriot missile defense systems to protect their troops deployed with the Saudi-led coalition in Yemen and civilian populations along the Yemen/Saudi Arabia border. Since the conflict began, the Houthi rebels have fired numerous Scud and Tochka missiles at the Saudi coalition forces, a number of which were intercepted by Patriot batteries.

Pacific Japan, South Korea, and the United States currently deploy Patriot systems in the Pacific to protect their populations and/or deployed troops. The United States has stationed Patriot batteries in South Korea since 1994 to guard against North Korea's short range ballistic and cruise missiles in addition to the South Korea's own Patriot batteries deployed as part of its missile defense system. Japan also deploys Patriot batteries as part of its missile defenses around Tokyo.

Timeline

2015: The latest Patriot PAC-3 missile, the MSE Improvement completed operational testing and is approved for initial production.

Mid 2000s: Under Foreign Military Sales agreements, several countries including Japan, the Netherlands, the UAE, Kuwait, and Taiwan purchased Patriot missiles, launchers, or upgrade kits. [5]

Operation Iraqi Freedom: U.S. Patriot batteries intercepted a total of nine enemy tactical ballistic missiles.

Late 1990s/early 2000s: The Patriot Advanced Capability – 3 (PAC-3) Upgrade was a major improvement using hit-to-kill technology to intercept incoming missiles. The PAC-3 also provides more fire-power per launcher since 16 PAC-3 missiles are loaded on to a launcher compared to four PAC-2 missiles. [6]

Late 1990s: The Guidance Enhanced Missile (GEM) was a post-war anti-tactical ballistic missile (ATBM) improvement to the PAC-2 missile. GEM-tactical (GEM-T) was also fielded as part of the GEM upgrades to the PAC-2.

1994: The United States stationed the 1st Battalion, 43rd Air Defense Artillery in the Republic of Korea in response to North Korea's threats to suspend the armistice on the Korean Peninsula.

January 17, 1991: First wartime intercept by a Patriot battery occurred during Operation Desert Storm. Over the course of the conflict, U.S. Patriot batteries brought down at least 11 enemy missiles.

Late 1980s/early 1990s: The PAC-2 was the first major missile upgrade for the Patriot system and was designed to intercept aircraft, tactical ballistic missiles, and cruise missiles. [7]

1988: The first Patriot units featuring the PAC-1 software upgrades were considered operational. [8]

Mid-late 1980s: The U.S. Army Missile Command began updating the Patriot missile's tracking ability and changing the missile's warhead to increase the probability of a "warhead kill."The Army tested these upgrades in 1986 and they are considered to be the Patriot PAC-1 upgrades.

1985: The Army recommended the deployment of Patriot systems to Europe and the Patriot was issued to units of the 32d Army Air Defense Command in Europe. At this time, the deployed Patriot system was only capable of shooting down aircraft. [9]

May 1982: The U.S. Army activated the first Patriot missile battalion. [10]

December 1981: The first Patriot missile was delivered. [11]

Terminal High Altitude Area Defense (THAAD)

Photo: Lockheed Martin

Facts	
Mobility	Mobile, ground-based
Targets	Short and Medium-range ballistic missiles
Role	Approx. 200 km, Medium-range, atmospheric interceptor
Status	**7 Batteries** (Army Requirement of 9), Deployed to Guam, United States
Prime Contractor	Lockheed Martin
Approximate Cost	Excluding support equipment, the cost of a full THAAD battery was $757 million in FY 2014

Photo: Missile Defense Agency

A THAAD interceptor is launched during a successful intercept test in 2013

Overview

The Terminal High Altitude Area Defense (THAAD) system provides the Ballistic Missile Defense System (BMDS) with a globally transportable, rapidly deployable capability to intercept and destroy ballistic missiles inside or just outside the atmosphere during their final, or terminal, phase of flight. THAAD Batteries consist of four main components: launcher, interceptor, radar, and fire control unit. The launcher is truck mounted and highly mobile, able to carry up to eight interceptors that can be rapidly fired and reloaded. Each THAAD interceptor has a range of about 200 km and uses hit-to-kill technology, in which the incoming threat is destroyed by kinetic energy. [1] THAAD uses the Army Navy/ Transportable Radar Surveillance (AN/TPY-2), which is the largest air-transportable X-band radar to search, track, and discriminate objects at a range of up 1,000 km and provide tracking data to the missile interceptor. [2] The THAAD fire control unit is the communications backbone of the battery linking the THAAD components and THAAD battery to external command and control and other BMDS elements. THAAD has undergone numerous intercept, non-intercept, and interoperability tests and boasts a current record of 13/13 successful tests.

Regional Defense Like Patriot Missile Defense Systems, THAAD intercepts missiles during their terminal phase of flight, but provides theater-wide protection that Patriot systems cannot. THAAD is designed to protect against short (up to 1,000 km) and medium (1,000 – 3,000 km) range ballistic missiles either inside or just outside the atmosphere, offering greater protection for troops by intercepting the incoming missile further from its target. THAAD is able to accept cues from Aegis, satellites, and other external sensors to extend its coverage area and can operate in concert with Patriot/PAC-3 and the Command, Control, Battle Management and Communications (C2BMC) system. [3] THAAD's greater radar coverage is also designed to counter mass raids and can be deployed as part of a layered defense system.

International Cooperation While THAAD is a relatively new missile defense system, a number of countries have expressed interest in deploying it. In December 2011, the United States and the United Arab Emirates (UAE) reached an arms deal worth $3.48 billion for the UAE to purchase two THAAD systems, missiles, radar system, parts, and training. [4] This arms deal made the UAE the first international recipient of the THAAD system. Other countries such as Saudi Arabia, Qatar and Japan have expressed interest in the system [5] and are in discussions with U.S. contractor, Lockheed Martin who produces the defense system.

Deployment The U.S. Army activated the first THAAD battery in 2008 at Fort Bliss in Texas. In April 2013, the U.S. deployed its first THAAD Battery to Guam to improve missile defenses around the island and counter the threat of North Korean missiles. This deployment came in response to North Korea's third nuclear test, threats to "sweep away" Guam's Andersen Air Force base, and North Korea's movement of two Musudan IRBMs to its East Coast. A THAAD battery remains deployed in Guam and studies are currently underway to consider the possibility of permanently deploying THAAD on the island.

Future Capabilities Future ballistic missile technologies require innovations in current missile defense capabilities and THAAD is being considered to meet future challenges such as hypersonic glide vehicles. The Thaad-ER (extended range) interceptor employs a two stage design and focuses on expanding the interceptor's range and providing a "kick-stage" to close the distance to the target and provide improved velocity at burnout, which allows for increased maneuverability to intercept targets. [6] Lockheed Martin, has invested in the Thaad-ER design as an industry concept and it is not currently an official MDA program. [7]

Strategic Implications

Asia The possible deployment or sale of THAAD systems to South Korea and/or Japan is an on-going discussion with implications for the Pacific region. Given its close proximity and North Korea's growing ballistic missile and nuclear weapons capabilities, South Korea and the United States are discussing the possibly of deploying THAAD on the Korean Peninsula. These talks, however, are complicated by China's outspoken opposition to the deployment of the THAAD system. China's concern stems from the range of the AN/TPY-2 radar that can detect missile launches and activity up to 1,000 km away. This would put parts of mainland China and parts of eastern Russia within range of the radar, causing China to express concern about the possibility of the U.S. monitoring its missile activity. Japan has also considered deploying THAAD, but faces the same road-blocks as South Korea.

Photo: Missile Defense Agency

Timeline

2015: The U.S. activated the fifth of seven planned THAAD Batteries at the end of the year.

2014: The fourth THAAD Battery was activated at Fort Bliss, Texas.

April 2013: The U.S. deployed a THAAD Battery to Guam to improve missile defenses around the island and counter the threat of North Korean missiles.

October 2012: The third THAAD Battery, D-2 battery, was activated at Fort Bliss, Texas.

December 2011: The United Arab Emirates became the first international recipient of the THAAD system.

October 16, 2009: The second THAAD Battery, the A-2 Battery, was activated at Fort Bliss, Texas. The battery consists of approximately 100 Soldiers in the 11th Air Defense Artillery Brigade, of the 32nd Army Air and Missile Defense Command. [8]

June 25, 2008: The THAAD system successfully conducted a test completing 35 out of 43 hit-to-kill intercepts since 2001 across all BMDS programs. [9]

May 2008: The first THAAD Battery, A-4 Battery, was activated at Fort Bliss, Texas.

October 27, 2007: The THAAD system successfully destroyed an "exo-atmospheric" target during this intercept test. [10]

June 27, 2007: MDA conducted the lowest altitude fly-out of a THAAD interceptor to date, demonstrating the system's ability to operate in a high-dynamic pressure environment with aero heating effects. [11]

January 27, 2007: A THAAD missile successfully intercepted a target representing a Scud type missile just inside earth's atmosphere. This was the first test of the THAAD system at the Pacific Missile Range Facility. [12]

July 12, 2006: FTT-03 was the first fully integrated THAAD flight test. It successfully demonstrated seeker characterization and intercepted a unitary target. [13]

November 22, 2005: Flight Test THAAD 01 (FTT-01) was conducted at White Sands Missile Range, New Mexico. This was a non-intercept test designed to test missile components and demonstrate missile egress, booster/kill vehicle (KV) separation, divert and altitude control system operation, and KV control. [14]

August 2, 1999: In the 11th flight test, the THAAD interceptor completed its first successful engagement of a target missile outside the earth's atmosphere and its first intercept of a warhead that had separated from its booster. [15]

July 1995: This non-intercept test successfully demonstrated the guidance and control system of the kill vehicle. [16]

April 1995: In its first flight test, the interceptor met its objectives by demonstrating proper launch, booster performance, booster/kill vehicle separation, radar-interceptor communication, flight-termination system operation, and in-flight environmental data collection. [17]

Other Systems

Avenger Facts	
Mobility	Highly mobile, Mounted atop a 4x4 Heavy High Mobility Multipurpose Wheeled Vehicle (HMMWV)
Role	Short-range surface-to-air shoot-on-the-move air defense weapon; targets cruise missiles, UAVs, low-flying, high-speed fixed-wing aircraft and helicopters
Status	Around 1,004 Avengers have been produced. Most are operated by the U.S., but Taiwan, Egypt, and the United Arab Emirates also employ the Avenger
Prime Contractor	Boeing


Photo: Florida National Guard

Avenger

First delivered in 1988, the Avenger air defense system is a vital element of the U.S. Army's Forward Area Air Defense (FAAD) and Line of Sight-Rear (LOS-R) architecture. The Avenger is a shoot-on-the-move, completely automated, day-and-night capable short-range air defense weapon that can acquire, identify, track, and engage air targets. Avenger includes a specialized HMMWV, Command, Control, and Intelligence (C2i), radars, platforms and Stinger missiles, and a .50 caliber machine gun. [1]

The Avenger also includes a 360 degree rotating turret with two missile pods—holding up to four Stinger missiles each (eight total)—mounted on a heavy HMMWV chassis. The turret drive is gyro-stabilized allowing the missile pod to maintain aiming direction regardless of vehicle motion.

Avenger is manned by a gunner who operates inside of the firing station in-between the two missile pods. The gunner uses a glass optical sight that displays missile seeker activate, uncage, and fire permit indications. Targets are acquired by using the optical sight or the Raytheon AN/VLR-1 Avenger FLIR (forward-looking infrared), which is a laser range finder and a video auto tracker. [2] FLIR sensors provide Avenger with a target acquisition capability in battlefield obscuration at night and in adverse weather.

In addition to the U.S. Army, the Marine Corps and Army National Guard also employ the Avenger around the globe. In 1991, the Avenger was deployed to support NATO troops during Operation Desert Storm. The short-range air defense system has also been fielded in Bosnia and South Korea. In 2003, the Avenger was deployed during Operation Iraqi Freedom and was employed as an air defense and ground security system. Since it was first delivered in 1988, the Avenger has undergone numerous upgrades to maintain its interoperability and effectiveness on the battlefield. [3]

C-RAM Facts	
Mobility	Highly mobile, mounted on road-mobile platform
Role	Protect deployed troops from rockets, artillery,and mortars
Status	Previously deployed in Iraq and Afghanistan; purchased by Australia and the United Kingdom
Prime Contractor	Raytheon, Northrop Grumman, L3 Communications, Lockheed Martin


Photo: U.S. Army

Counter-Rocket, Artillery, Mortar (C-RAM)

The Counter-Rocket, Artillery, Mortar (C-RAM) / Indirect Fire Protection Capability (IFPC) system was developed early during Operation Iraqi Freedom/Enduring Freedom in order to protect ground forces and forward operating bases from the threat of rockets, artillery, and mortars. C-RAM is made up of variety of systems which provide the ability to sense, warn, respond, intercept, command and control, shape, and protect deployed forces.

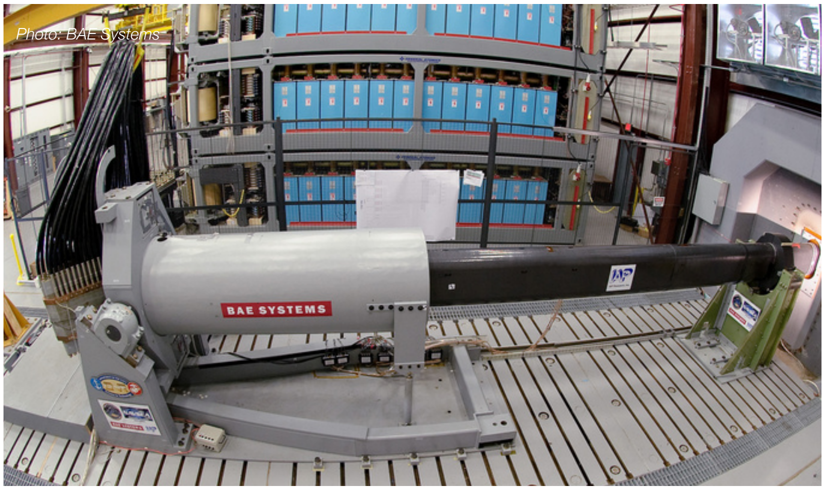
C-RAM components include the Forward Area Air Defense Command and Control (FAAD C2), Land-based Phalanx Weapon Systems (LPWS), Lightweight Counter Mortar Radars (LCMR), Firefinder radars, Ka-band Multi-function Radio Frequency Systems (MFRFS), Air and Missile Defense Workstation (AMDWS), and several other components that contribute to system intercept and communications.

A main component of the C-RAM system is the LPWS, which is modified from the U.S. Navy MK-15 MOD 29 Block IB, Baseline 2 Close-In Weapon System, and mounted on a commercial 35 ton semi-trailer for land-based operations. The M61A1 20mm Gatling gun is capable of acquiring its target and firing at a rate of 4,500 rounds per minute. The Forward Area Air Defense Command and Control (FAAD C2) system integrates the sensors, weapons, and warning systems for C-RAM intercept.


Photo: U.S. Army

C-RAM was operationally deployed in Iraq and Afghanistan, where its sense and warn capabilities provided timely warning of more than 2,500 rocket and mortar attacks against C-RAM equipped forward operating bases. C-RAM was also purchased by Australia and the United Kingdom.

Electromagnetic Railgun Facts	
Mobility	Ship-mounted and highly mobile
Range	~100 nautical miles
Projectile Velocity	Up to Mach 6
Role	Provide Naval ships with precise surface fire support or land strikes, ship defense, and ability to deter or eliminate enemy vessels.
Status	Testing phase
Prime Contractor	BAE Systems in cooperation with Office of Naval Research



BAE Systems Electromagnetic Railgun in a test facility

Electromagnetic Railgun

The EM Railgun is a long-range weapon that fires projectiles using electricity in the form of electromagnetic propulsion. Magnetic fields created by high electrical currents accelerate a sliding metal conductor, or armature, between two rails to launch projectiles from zero to mach 6 in about 10 milliseconds.

The EM Railgun is planned to be mounted on a ship and will store electricity generated by the vessel over several seconds in the pulsed power system, then send an electric pulse to the railgun creating an electromagnetic force and launching the projectile.

The Projectile weighs roughly 23 lbs and uses the extreme speed and kinetic energy on impact to eliminate the threat. The use of kinetic energy eliminates the hazards of managing high explosives aboard the ship and unexploded ordnance on the battlefield.

The EM Railgun project is finishing up its testing phase and is awaiting a decision on whether it will enter the at-sea prototype phase or be outfitted directly on a Zumwalt-class destroyer.

MEADS Facts	
Mobility	Highly mobile, mounted atop a road-mobile platform
Role	Protect against tactical or medium-range ballistic missiles, cruise missiles, unmanned aerial vehicles, and aircraft
Frequency	Radars work in Ultra High Frequency and X-band
Status	Several countries are considering or have announced plans to purchase MEADS including Germany, Poland and Turkey
Prime Contractor	MEADS International (partnership of MBDA Italia, MBDA Deutschland, and Lockheed Martin)


Photo: Lockheed Martin

Medium Extended Air Defense System (MEADS)

Medium Extended Air Defense System (MEADS)

The Medium Extended Air Defense System (MEADS) is a missile defense system developed to meet International Common Operational Requirements and is jointly developed by the United States, Germany, and Italy. MEADS consists of five elements: surveillance radar, tactical operations center, multifunction fire control radar, launcher/reloader, and the certified missile round.

The surveillance radar (SR) of MEADS provides 360 degree, long range coverage with a pulse doppler radar and an active phased array antenna operating in the ultra-high frequency (UHF) band. The SR is capable of detecting multiple threats, distinguishing friend from foe, and relaying data to the tactical operations center (TOC). Like the SR, the multifunction fire control radar (MFCR) provides 360 degree coverage, and uses X-band radar for target tracking and engagement. The MFCR is only engaged when required by the system to track and intercept a target. Both the SR and MFCR are light weight and highly maneuverable, enabling quick and easy deployment.

The battle management command, control, communications, computers and intelligence (BMC4I) TOC provides real-time links for battle management, engagement, and force operations. The TOC features a common software package tailored for each nation and is interoperable with external interfaces such as Airborne C3 Systems, Joint Land Attack Cruise Missile Defense Elevated Netted Sensor System (JLENS), Joint Tactical Ground Stations/Multi-Mission Mobile Processor (JTAGS M3P), and Ground-based and Naval Air Defense Systems (ADS).

The MEADS launcher holds up to eight PAC-3 MSE missiles and can be elevated to a near-vertical launch angle. The reloader for the launcher can perform a full or partial reload and features a pallet load handling and erection system. Both the launcher and reloader can be integrated with each country's preferred transport vehicle. The certified missile round (CMR) or baseline missile for MEADS is the Patriot Advanced Capability-3 Missile Segment Enhancement (PAC-3 MSE). The PAC-3 MSE features increased performance and greater altitude and range over earlier models.


Photo: Lockheed Martin

Israel's Ballistic Missile Defense Program

Overview Israel's perilous strategic environment has made missile defense a critical tool for the small nation. It is constantly threatened by mortar, rocket, and ballistic missile attacks from regional state and non-state actors. States hostile to Israel—such as Iran, Syria, and others—pose an existential threat and have done so since Israel's formation in 1948. However, non-state actors like Hezbollah and Hamas have emerged to increase the risk of missile, mortar, and artillery strikes on Israeli territory. Working in cooperation with the United States, Israel has come to develop one of the world's most sophisticated layered ballistic missile defense (BMD) architectures to counter these threats.

Israel's Iron Dome missile defense system launches an interceptor

Iron Dome The lowest tier of Israel's layered BMD architecture is Iron Dome, which was independently developed by Israel and became operational in early 2011. Iron Dome is a short-range anti-rocket system that has made headlines as one of the best modern missile defense systems in the world. Iron Dome sets itself apart with the ability to predict the point of impact for incoming projectiles. This capability enables Iron Dome to prioritize the engagement of targets, allowing the BMD system to intercept projectiles that threaten populated areas, while ignoring ordinance that is predicted to land in uninhabited regions. In 2012, Iron Dome defended Israel from an artillery and short-range ballistic missile attack, during which the BMD system intercepted 90 percent of short-range projectiles fired at its territory. Between 2012 and 2014, Israel upgraded its tracking and firing mechanisms and expanded the number of batteries from five to nine. The U.S.-made Patriot missile system is also employed by Israel to bolster the lower tier of its layered missile defense system.

In December of 2015, David's Sling completes a milestone in testing before being declared operational and delivered to the Israeli Air Force

David's Sling Recently tested and soon to be deployed, David's Sling makes up the middle tier of Israel's layered BMD architecture and is designed to intercept short- and medium-range ballistic missiles in the terminal phase. The system was co-developed by Israel's Rafael Advanced Defense Systems and U.S.-based Raytheon. Using its two-stage Stunner interceptor and multi-mission radar, David's Sling is employed as a flexible, multipurpose weapon system capable of engaging aircraft, cruise missiles, and ballistic missiles. [1] Testing for David's Sling began in 2014 and the BMD system is expected to undergo operational deployment in early to mid-2016.

Arrow The upper tier of Israel's layered BMD infrastructure is the Arrow Weapon System (AWS). AWS was co-developed with the United States to provide Israel with the capability to defend itself against imminent and developing ballistic missile threats. Testing and operational use of AWS also provides the United States with critical data and technology for its own BMD programs. Components of AWS include Arrow anti-missile interceptors, the Elta EL/M "Green Pine" early warning radar, the Elisra "Golden Citron" command and control center, and the Aerospace Industries "Brown Hazelnut" launch control center. The currently deployed two-stage Arrow 2 interceptor is designed to counter short- and medium-range ballistic missiles in the ascent, midcourse, and terminal phases. An upgraded version of the Arrow interceptor called Arrow 3 is currently being co-developed by Israel and the United States. The two-stage Arrow 3 interceptor has a longer range than Arrow 2 and employs an exo-atmospheric kill vehicle (EKV) to intercept its targets. During intercept tests, Arrow 3 has demonstrated an improved ability to discriminate decoys from warheads and intercept missile threats outside of the Earth's atmosphere. [2]

Iron Dome intercepts a projectile above the Israeli town of Sderot on July 21, 2014

Photo: REUTERS/Baz Ratner

Section 3 - U.S. Sensor Systems

Beale Early Warning Radar located at Beale Air Force Base, California.

Photo: Missile Defense Agency

AN/SPY-1

Facts	
Mobility	Sea-based version is highly mobile; land-based has low mobility
Role	Primary radar for Aegis BMD
Deployment	Deployed on all 85 U.S. Navy vessels equipped with the Aegis Combat System (including all 33 Aegis BMD-capable vessels); deployed at Aegis Ashore sites in Romania and Kauai, Hawaii.
Frequency	S-Band
Range	Up to 310 km (estimated)
Prime Contractor	Lockheed Martin, Raytheon

Photo: U.S. Navy

The USS Lake Erie (CG-70) with its SPY-1B radar panel clearly visible

Overview

The Army/Navy Joint Electronics Type Designation System (AN/SPY-1) is critical for the U.S. Navy's aerial radar infrastructure and is a key component of Aegis Ballistic Missile Defense System at sea and on land. U.S. Navy cruisers and destroyers employ SPY-1—in addition to a number of foreign vessels—for Aegis Sea-Based BMD, while on land, the radar system is utilized by Aegis Ashore missile defense sites. Developed by Lockheed Martin, SPY-1 radar was originally designed as an air defense system, but has been upgraded to include a ballistic missile defense (BMD) capability. SPY-1's passive electronic scanning system is computer controlled, using four complementary antennas to provide full 360 degree coverage. It operates in S-band and is a multi-function phased-array radar capable of search, automatic detection, transition to track, tracking of air and surface targets, and missile engagement support.

The SPY-1 can maintain continuous radar surveillance while automatically tracking more than 100 targets at one time. Public numerical figures on the SPY-1's detection range claim that it can detect a golf ball-sized target at ranges in excess of 165 km. When applied to a ballistic missile-sized target, the SPY-1 radar is estimated to have a range of 310 km. Since the system was originally designed for blue water and littoral operations, the SPY-1 had to be modified for use on land and close to shore by modifying the radar to look above the terrain to avoid causing excessive false targets from land clutter. Configuration changes to mitigate this technical issue have made it more difficult for AN/SPY-1 to identify and track low and fast targets.

Regional Defense—Engagement Capability Aegis BMD systems are capable of detecting, tracking, targeting, and intercepting cruise and ballistic missile targets. After detecting and identifying a regional missile threat, Aegis BMD can engage and intercept the target using Standard Missile variants partially guided by tracking information provided by SPY-1. Aegis BMD-equipped cruisers and destroyers are being equipped with the capability to intercept short- and medium-range ballistic missiles as quickly as 10 seconds after the radar "sees" the missile's movement.

Homeland Defense—Long-Range Surveillance and Tracking Aegis Destroyers on BMD patrol detect and track intercontinental ballistic missiles with SPY-1, reporting tracking data to the Ballistic Missile Defense System (BMDS). The BMDS shares tracking data to cue other missile defense sensors and provides fire control data to Ground-based Midcourse Defense (GMD) interceptors located at Fort Greeley, Alaska and Vandenberg Air Force Base, California. To date, twenty-one Aegis Cruisers and Destroyers have been upgraded with the Long-Range Surveillance and Tracking capability. At-sea tracking events and flight tests have verified the capability to track intercontinental ballistic missiles and demonstrated the connectivity and reliability of long-haul transmission of tracking data (across nine time zones), which is necessary to support missile defense situational awareness, target acquisition, and engagements.

Deployment Variants of the AN/SPY-1 radar are employed by all Aegis BMD systems, both on land—with Aegis Ashore—and at sea—on Ticonderoga (CG-47) Class Aegis Cruisers and Arleigh Burke (DDG-51) Class Aegis Destroyers. As of June 2015, there are 33 Aegis BMD-capable combatants in the U.S. Navy, 5 cruisers (CGs) and 28 destroyers (DDGs). Of the 33 ships, 16 are assigned to the Pacific Fleet and 17 to the Atlantic Fleet. U.S. allies in possession of Aegis technology—namely Japan, the Republic of Korea, Norway, and Spain—also field SPY-1 radar aboard their Aegis vessels.

Timeline

2018 (planned): Phase IV of the EPAA mandates a second operational Aegis Ashore missile defense system and corresponding land-based SPY-1 radar be established in Poland.

2015: Aegis Ashore equipped with one land-based SPY-1 radar was deployed in Romania as mandated by Phase III of the EPAA. Four U.S. Aegis destroyers deployed to Spain—as directed by the EPAA—equipped with SPY-1D radar.

2005: The SPY-1D(V) variant is deployed for the first time aboard the USS Pinckney, an Arleigh Burke class destroyer.

1991: The SPY-1D variant was first deployed aboard the USS Arleigh Burke (DDG-51), the first of the Arleigh Burke class Aegis destroyers.

1982: The SPY-1B variant was first deployed aboard the USS Princeton (CG-59).

1981: The first Aegis cruiser, the USS Ticonderoga (CG-47), which was equipped with SPY-1 radar, was commissioned.

1970s: the SPY-1 program began as part of the Aegis weapon system development process. Increased precision track data via radar signal processing upgrades, improving both Long-Range Surveillance and Tracking and engagement capabilities.

Photo: Missile Defense Agency

Aegis Ashore with an SPY-1 radar panel clearly visible on the deckhouse

SPY-1 Variants

Four different SPY-1 radar variants are currently deployed on U.S. ships. The original SPY-1 variant was a test version of the radar that was never deployed. The SPY-1A and 1B variants are carried by Aegis cruisers and have two antenna faces on each of the two deckhouses, while the SPY-1D and 1D(V) variants are carried by Aegis destroyers and have four antenna faces, each antenna covering slightly more than 90° in azimuth. All U.S. Aegis systems that have been upgraded for BMD are equipped with either the 1B, 1D, or 1D(V) version.

- ***SPY-1A*** The SPY-1A was installed on the first Aegis cruiser, the USS Ticonderoga (CG 47), which was deployed in 1981. The U.S. Navy is currently in the process of phasing out the SPY-1A and most Aegis cruisers employ the upgraded 1B variant.

- ***SPY-1B*** This SPY-1 variant has an improved antenna that is better suited to operate in a cluttered environment. The SPY-1B also has around twice the average power of the SPY-1A. 1B is currently used by most Aegis cruisers.

- ***SPY-1D*** The SPY-1D was the first SPY-1 radar developed for Aegis destroyers. This variant is similar to the 1B version, however, one transmitter is used by the 1D to drive all four radar faces, which are all located on a single deckhouse. This upgrade also improves the radar's performance against low-altitude, reduced radar cross-section targets in heavily cluttered environments and in the presence of electronic countermeasures. The four U.S. destroyers based in Rota, Spain in 2015 as part of the European Phased Adaptive Approach (EPAA) are equipped with SPY-1D radar.

- ***SPY-1D(V)*** Called the "littoral warfare" radar, the SPY-1D(V) improved clutter rejection and moving target detection, enhancing the capability of Aegis radar in cluttered environments.

- ***SPY-1F*** This variant—known as the "frigate array radar system"—is designed for Aegis frigates and is a smaller version of the SPY-1D. While not employed by the U.S. Navy, the SPY-1F is used by Norway on its Fridtjof Nansen-class Aegis frigates.

A smaller variant of SPY-1, the SPY-1F radar, atop a Norwegian Fridtjof Nansen-class Aegis frigate

Current Developments

The next effort to modernize the Aegis fleet is called Aegis Advanced Capability Build 20, which calls for a new version of the DDG-51 destroyer equipped with an improved radar system called the Air and Missile Defense Radar (AMDR). Developed by Raytheon, AMDR—officially designated AN/SPY-6—is the Navy's next generation integrated air and missile defense radar. Comprised of both S- and X-band radars, along with a Radar Suite Controller (RSC), the AMDR promises to provide greater detection ranges and increased discrimination accuracy over the SPY-1D(V). DDG-51 destroyers equipped with AMDR are currently scheduled to enter service in 2023.

Concept design of the Air and Missile Defense Radar (AMDR)

AN/TPY-2

Photo: Raytheon

Facts	
Mobility	Transportable by air, ship, and truck; moderate mobility
Role	Forward-based radar for BMDS; Primary terminal radar for THAAD
Deployment	Israel, Turkey, Arabian Gulf, Japan, Guam (THAAD), and Fort Bliss, Texas (THAAD)
Frequency	X-band
Range	1,000 km
Prime Contractor	Raytheon

Overview

The Army/Navy Transportable Radar Surveillance (AN/TPY-2), specifically designed for ballistic missile defense, is deployed to enhance the BMDS by adding a robust defense against a wide range of threats and to provide support for increased protection. The TPY-2 is a high-resolution, X-band, phased array radar that is transportable by air, ship, and truck. It is also deployed with a command and control interface, a radar support trailer, generators, and supply containers.

Operated by the U.S. Army, the TPY-2 is employed to provide regional and strategic ballistic missile threat data to the entire Ballistic Missile Defense System (BMDS) through the Command and Control, Battle Management, and Communications (C2BMC) system. The X-band frequency has the advantage of being able to distinguish between smaller objects, such as a warhead, against space debris. This discrimination capability is called “range resolution,” and allows the TPY-2 radar to provide detailed tracking and discrimination data to the BMDS. TPY-2 can be set to one of two settings, each designed to meet different requirements: forward-based mode for boost phase surveillance and terminal mode for terminal phase surveillance and Terminal High Altitude Area Defense (THAAD) fire support.

Forward-Based Mode—Boost Phase Surveillance Forward-based TPY-2 radar coupled with layered sensors give the Ballistic Missile Defense System an earlier and continuous tracking and discrimination capability with more opportunities to engage the target, resulting in a greater probability for a successful intercept. It performs autonomously or is cued in coordination with other sensors, passing target data to the command and control system for use by other sensors. When in forward-based mode, the TPY-2 surveils for all classes of ballistic missiles in the boost phase of their trajectory. It is able to acquire, track, discriminate, classify, identify, and estimate the trajectory parameters of threat missiles and missile components. Once this information is gathered, it is passed along to (BMDS) tracking, discrimination, and fire control radars downstream. This approach provides overlapping sensor coverage, the potential to extend the BMDS battlespace, and the ability to complicate an enemy’s ability to penetrate the defense system.


Photo: Raytheon

Terminal Mode—Terminal Phase Surveillance When deployed with THAAD, TPY-2 is placed in terminal mode, allowing it to detect missile threats in the terminal phase of their trajectory and provide fire support for missile intercept. When in terminal mode, TPY-2 works directly with THAAD to surveil, detect, track, discriminate, and provide fire control support against short- and medium-range ballistic missiles as they descend towards their target. Once a terminal-phase threat is detected and tracked, TPY-2 then provides fire control support for THAAD, which launches an interceptor—guided by the TPY-2—to intercept the ballistic missile target.

Deployment Ten total AN/TPY-2 radars have been produced, with an additional two in development. TPY-2 is deployed in forward-based mode in Israel, Turkey, the Arabian Gulf, and Japan. In Israel, Turkey, and the Arabian Gulf, forward-based TPY-2 radar is employed to surveil for boost-phase ballistic missile threats launched out of the Middle East. Information on these ballistic missiles is then provided to the BMDS and Aegis BMD systems in Europe as part of the European Phased Adaptive Approach (EPAA). In Japan, two TPY-2 radars are used—at Kyogamisaki Sub Base and Shariki Military Base—to surveil for boost-phase ballistic missile threats launched out of North Korea. Additionally, there are five total THAAD batteries, one in Guam and the remaining four at Fort Bliss, Texas. Each THAAD battery is equipped with its own AN/TPY-2 radar in terminal mode.

European Phased Adaptive Approach

The AN/TPY-2 is a major factor of the EPAA. In 2011, as mandated by Phase I of the EPAA, an AN/TPY-2 radar was deployed in Turkey in forward-based mode to detect ballistic missile threats coming out of the Middle East—particularly Iran. The AN/TPY-2 radar in Turkey provides the BMDS with continuous tracking and discrimination capability and more opportunities to engage a target originating in the Middle East. Radar tracks from AN/TPY-2 are used to provide early tracking information that increases the capability of regional missile defense assets in Europe. When coupled with other sensors involved in the EPAA, the TPY-2 in Turkey helps to provide a greater probability for a successful missile intercept.

Current Developments

In 2012, the U.S. National Research Council submitted a report that recommended an improved TPY-2 radar as part of the Ground-based Midcourse Defense system for the continental United States. On the ground, five integrated and rotatable TPY-2 radars would be added, each with X-band uplink and downlink modes. Four of these would be co-located with four current Upgraded Early Warning Radar (UEWR) sites. The additional TPY-2 radar would be placed at Grand Forks, ND, which currently houses the 10th Space Warning Squadron. It has been argued that the TPY-2's X-band wavelength provides better discrimination between warheads and decoys than current UEWR radars.

Timeline

April 2013: THAAD battery—with corresponding AN/TPY-2 radar—deployed to Guam in response to threats from North Korea.

September 2012: The U.S. military and Japan agree to place a second TPY-2 radar in Japan.

July 2012: AN/TPY-2 deployed to the Arabian Gulf.

September 2011: Turkey agreed to emplace an AN/TPY-2 radar, as part of the EPAA Array system. The radar will be deployed facing Iran and alined to U.S. Navy systems.

September 2008: The U.S. Army's European Command deployed an AN/TPY-2 radar to Israel's Nevatim Air Force Base in the Negev desert. A 120-member support team accompanied the radar.

2007: The U.S. deployed its first AN/TPY-2 Radar to Japan to provide forward-based surveillance and improve missile defense in the region.

July 2007: Raytheon announced a $304 million contract from the MDA to develop advanced tracking and discrimination capabilities for the BMDS forward based AN/TPY-2 radar.

February 2007: Raytheon received a $20 million modification contract that could go up to $212.2 million to manufacture, deliver, and integrate the AN/TPY-2 radar component of the THAAD ABM system.

Command, Control, Battle Management and Communications (C2BMC)

Photo: Missile Defense Agency

Facts	
Role	Links sensor-interceptor-communications elements into one coordinated system utilizing the best offensive/defensive attributes of each element, ensuring the highest BMDS capability for protection against all types of ballistic missile threats in all regions and in any phase of flight
Status	More than 70 C2BMC workstations are fielded throughout the United States missile defense enterprise
Prime Contractors	Northrop Grumman, Lockheed Martin

Overview

The Command and Control, Battle Management and Communications (C2BMC) System is a software package used by the Missile Defense Agency and combatant commands to support ballistic missile defense systems. Specifically, STRATCOM, NORTHCOM, EUCOM, PACOM and CENTCOM all use the C2BMC software for a variety of tasks including; planning of missile defense engagements, situational awareness during engagements, managing missile trajectory calculation software, sensor management and control of AN/TPY-2, engagement monitoring, data exchange, and network management.

System Information The C2BMC system is currently fielded at STRATCOM, NORTHCOM, EUCOM, PACOM, CENTCOM, numerous Army Air and Missile Defense Commands, Air and Space Operations Centers, and other supporting warfighter organizations. The C2BMC displays information from various satellites to provide situational awareness on BMD system status, system coverage, and ballistic missile trajectories. C2BMC provides coordination functions when multiple missile defense systems are used to engage a target. The C2BMC S6.4 suite provides command and control for forward based AN/TPY-2 radar systems, and, through its Global Engagement Manager Suite, provides updated sensor management, missile trajectory processing, and reporting. C2BMC sends information from forward based AN/TPY-2 and AN/SPY-1 to national missile defense systems. It also sends information from forward based AN/TPY-2 to theater missile defense systems.

Capabilities Tests in October of 2013 for CENTCOM and EUCOM showcased the ability of C2BMC to provide data focused on allowing greater discrimination from radar systems between missiles and debris. The December 2013 PACOM Fast Phoenix test demonstrated accurate and timely data sharing between Aegis BMD and C2BMC. March 2014 tests demonstrated interoperability with theater BMD elements to provide better situational awareness, including starting the systems during the initial launch of the missile. This capability was further demonstrated in the August 2014 Fast Exchange ground tests, where C2BMC managed three AN/TPY-2 radars and facilitated the passing of filtered missile trajectory data between these systems and Aegis BMD, THAAD, and Space-Based Infrared System elements.

Future Development Development of C2BMC Spiral 8.2 is scheduled for FY 2017-18 to patch issues found during ground and flight-testing in situational awareness and interoperability. MDA and Red Teams from the Threat Systems Management Office conducted stress tests of future C2BMC software spirals to reduce vulnerability to cyber attacks. These Red Teams, consisting of designated hackers who probe the software system for vulnerabilities used the newly created DOD Enterprise Cyber Range Environment (DECRE) to simulate actions that adversaries would take to compromise cyber security. MDA is also working to integrate C2BMC with the Army's Integrated Battlefield Control System (IBCS) to allow exchanges of data on ballistic missiles between the systems.

Defense Support Program (DSP)

Photo: Northrop Grumman

Facts	
Mobility	Satellites in GEO
Role	Strategic and tactical missile launch detection
Status	Five satellites in geosynchronous orbit
Prime Contractor	Northrop Grumman

Overview

The Defense Support Program (DSP) satellites provide early warning for Intercontinental Ballistic Missile launches. It uses infrared detectors that are capable of sensing heat from missile plumes against the cooler background of the earth. Since 1970, the DSP has been a critical component of the North American Aerospace Defense Command's (NORAD) Tactical Warning and Attack Assessment System. The 460th Space Wing, with headquarters at Buckley Air Force Base, Colorado, has units that operate DSP satellites and report warning information, via communications links, to the North American Aerospace Defense Command/U.S. Northern Command and U.S. Strategic Command early warning centers within Cheyenne Mountain Air Force Station. These centers immediately forward data to various agencies and areas of operations around the world. [1] DSP's effectiveness was proven during Operation Desert Storm, when DSP detected the launch of Iraqi Scud missiles and provided warning to civilian populations and coalition forces in Israel and Saudi Arabia. [2]

DSP has a history of launching atop the Titan III and IV family of launch vehicles (to include the Titan addition of the Solid Rocket Motor Upgrade) with one exception to date. DSP-16 was launched aboard NASA's Space Shuttle Atlantis in November 1991. DSP was first deployed on November 6, 1970 while the 23rd and final DSP satellite launched in December 2007. DSP-23 was the first operational satellite to launch atop Boeing's Delta IV Heavy Evolved Expendable Launch Vehicle (EELV). In recent years, scientists have developed methods to use DSP's infrared sensor as part of an early warning system for natural disasters like volcanic eruptions and forest fires. [3]

Current Status

Currently five DSP satellites are operational. They were launched in the mid- to late-80s, and three function while the other two serve as backups. [4] In 1995, the Space-Based Infrared System (SBIRS) was announced to provide a seamless operational transition from DSP to the nation's next-generation Overhead Persistent Infrared sensors. SBIRS would meet jointly defined requirements of the defense and intelligence communities in support of missile early warning, missile defense, battlespace awareness, and technical intelligence mission areas. [5]

Timeline

November 10, 2007: Final DSP launch

1989 – 2007: Block 5: DSP-1, 10 satellites launched

1984-1987: Block 4: Phase II Upgrade, 2 satellites

1979-1984: Block 3: Multi-Orbit Satellite Performance Improvement Modification (MOS/PIM), 4 satellites

1975-1977: Block 2: Phase II, 3 satellites

1970-1973: Block 1: Phase I, 4 satellites

November 6, 1970: The U.S. Air Force launched a classified satellite on a Titan IIIC rocket from Launch Complex 40 at Cape Canaveral Air Force Station, Florida.

1960s: The Defense Support Program grew out of the successful space-based infrared Missile Defense Alarm System known as MIDAS. The first successful launch of MIDAS was May 24, 1960. Between 1960 and 1966, 12 MIDAS launches deployed four different types of increasingly sophisticated sensors — leading the way to the development, launch and use of DSP.

Joint Land Attack Cruise Missile Defense Elevated Netted Sensor System (JLENS)

Photo: Raytheon

Facts	
Mobility	Land-based tethered aerostat system, moderate mobility
Role	Detect and track cruise missiles, drones, rockets, vehicles, and maritime surface vessels
Range	Detect threats up to 540 km away
Status	Awaiting approval and funding to resume operational exercise, unlikely to receive funding in the FY2017 budget
Prime Contractor	Raytheon

Photo: Raytheon

Overview

The Joint Land Attack Cruise Missile Defense Elevated Netted Sensor System or JLENS consists of two large, unmanned, helium-filled aerostats that carry radar systems designed to detect and track threats such as cruise missiles, drones, aircraft, large caliber rockets, vehicles, and maritime surface vessels. The JLENS aerostats can float up to 10,000 feet and provide 360 degree coverage for an area approximately the size of Texas. It can also detect threats over the horizon, up to 340 miles away, and can stay airborne for up to 30 days providing 24/7 continual protection. [1] JLENS also integrates with defensive systems such as the Patriot missile defense system, the Standard Missile 6 (SM-6) employed by Aegis BMD systems, Advanced Medium Range Air-to-Air Missiles (AMRAAM), and the National Advanced Surface-to-Air Missile System (NASAMS), as well as other command and control and defensive systems. [2]

Deployment

JLENS is deployed as a pair of aerostats: one carrying surveillance radar systems and the other carrying fire control radar systems. In December 2014, the first surveillance aerostat was moored at Aberdeen Proving Ground (APG) near Baltimore, Maryland with the fire control aerostat deployed several weeks later. The North American Aerospace Defense Command (NORAD) is leading the three-year operational exercise of the JLENS along with the Army's A Battery, 3rd Air Defense Artillery under U.S. Northern Command.

Strategic Implications

The potential applications for JLENS go far beyond homeland cruise missile defense, as it has shown value in detecting and relaying information, and integrating with other deployed sensor and missile defense systems. JLENS has the ability to cover up to 340 miles makes it appealing for use by Combatant Commanders to protect deployed troops and track and identify potential targets. JLENS can operate 24/7 and stay afloat for up to 30 days at a time, which makes it a prime surveillance tool to replace surveillance aircraft, which operate at a higher cost and are restricted by refueling needs. The ability of JLENS to track vehicles and surface ships also increases its potential for deployment in regions such as the Middle East.

The JLENS system also has applications to protect U.S. and allied forces in the Pacific. Deployment of JLENS could allow the U.S., South Korea, and Japan to monitor not only potential missile launches from North Korea, but also to identify and track its mobile launchers and surface ships that may pose a significant threat. JLENS would be able to integrate with already deployed missile defense systems such as Aegis BMD ships and Patriot batteries, as well as possible future defense systems in the region such as the Terminal High Altitude Area Defense (THAAD) system. JLENS use in the Pacific could also protect U.S. forces and ships from the cruise missile threat emanating from countries such as Russia and China.

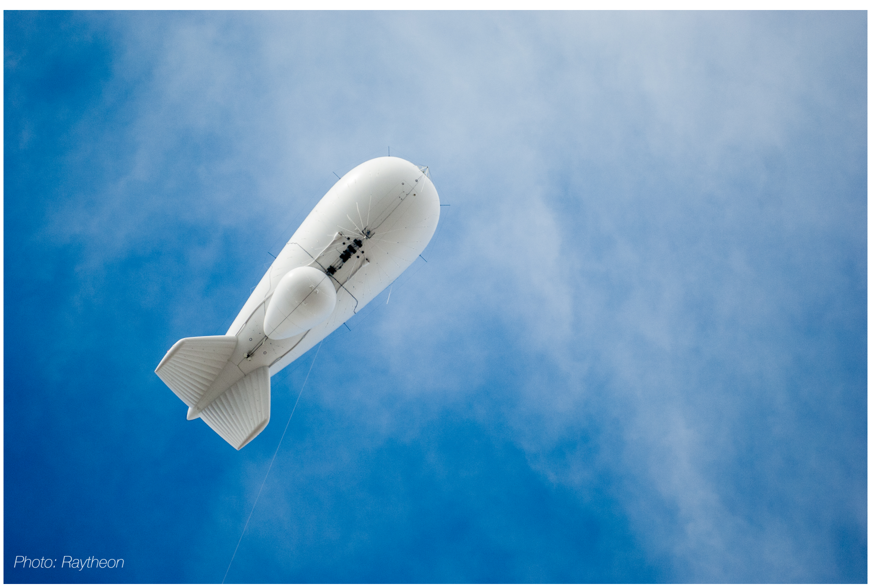


Photo: Raytheon

Timeline

March 2016: The JLENS program did not receive the unanimous approval needed from the Senate Defense Appropriations Subcommittee to reprogram $27.2 million in funding for the JLENS program, making it unlikely for the program to receive funding in the FY2017 budget.

February 2016: Defense Secretary Ash Carter approved restarting the suspended JLENS exercise, but the program needs Congressional action to continue. [3]

October 28, 2015: The JLENS fire-control radar aerostat broke free from its tether during extreme weather conditions and floated for several hours before coming down in rural Pennsylvania. The JLENS exercise was suspended following this incident.

December 2014: NORAD deployed the JLENS surveillance aerostat at Aberdeen Proving Ground in Maryland, followed several weeks later in 2015 by the JLENS fire control aerostat. This began a three-year operational exercise of the system.

July 2013: JLENS supported an IFC test in which an Air Force F-15 targeted a drone.

September 2012: JLENS provided IFC targeting information to a Navy Aegis BMD system using Cooperative Engagement Capability datalinks during a joint JLENS-Navy Integrated Fire Control-Counter Air (NIFC-CA) missile flight test. [4]

April 2012: JLENS provided support for an Integrated Fire Control (IFC) live missile flight test that resulted in the successful intercept of a fixed-wing target drone aircraft in a controlled test environment. [5]

July 14, 2010: The JLENS aerostat deployed to a new high of 10,600 feet above Mean Sea Level, carrying a mock payload of approximately 5,000 pounds.

April 14, 2010: A JLENS aerostat conducted a successful first launch to 1,000 feet above ground level and recovery to 300 feet at the Utah Test and Training Range (UTTR) Echo Site. [6]

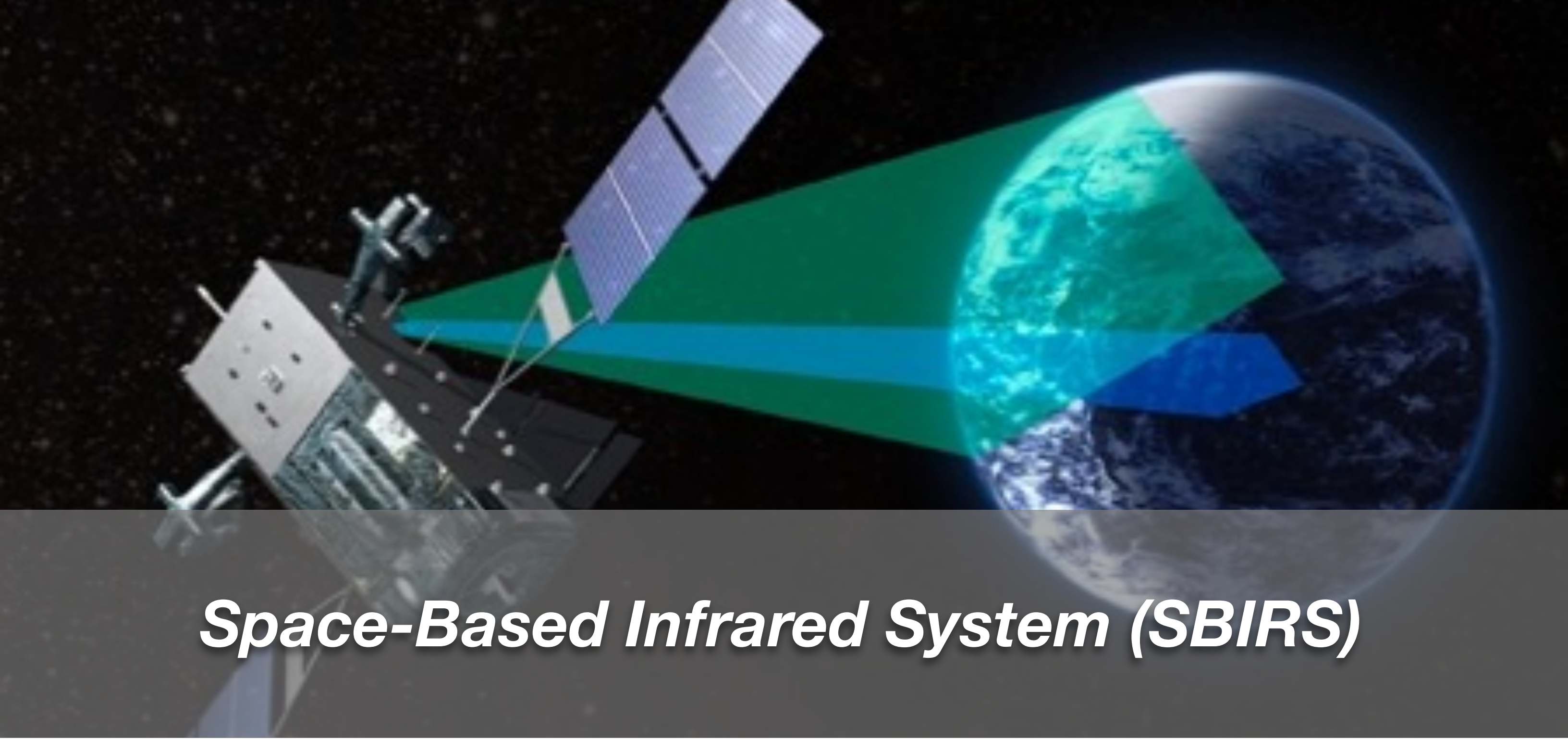
March 2008: Preliminary design review of the JLENS completed. [7]

April 2007: Raytheon completed a successful system functional review of the JLENS.

November 15, 2005: Raytheon received a $1.3 contract to develop and tests the JLENS radar system.

1999: During the All Service Combat Identification and Evaluation Team (ASCIET) exercise, a 15m aerostat with the type of technology found in the current JLENS was deployed with a Cooperative Engagement Capability relay on a mobile mooring station. This relay allowed the Army's Patriot air defense system and the Navy's AEGIS weapon system to exchange radar data.

January 30, 1998: The U.S. Army SMDC awarded a contract to Raytheon Company for the JLENS system and Raytheon began working on small scale models.



Space-Based Infrared System (SBIRS)

Photo: Lockheed Martin

Facts	
Mobility	Satellites and sensors in GEO and HEO
Role	Mission areas include missile defense, missile warning, technical intelligence and battlespace awareness
Status	Two GEO satellites and three HEO sensors are currently operational
Prime Contractor	Lockheed Martin

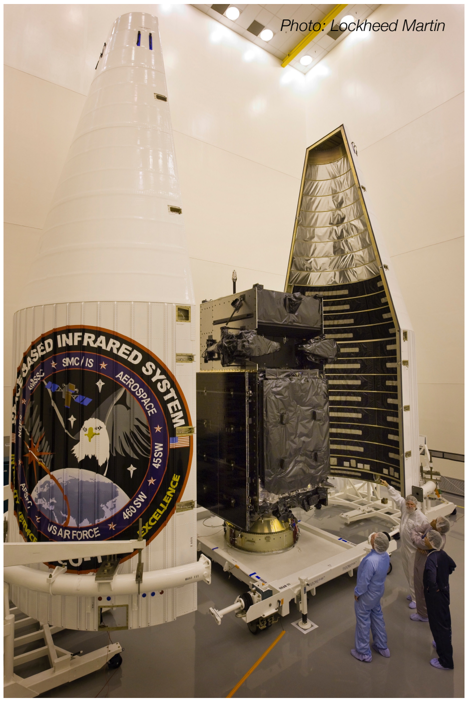


Photo: Lockheed Martin

SBIRS GEO-1 preparing for liftoff aboard an Atlas V rocket

Overview

The Space-Based Infrared System (SBIRS) is designed to support the defense and intelligence communities and provide global surveillance capabilities in four key mission areas: missile defense, missile warning, technical intelligence, and battlespace awareness. SBIRS is made up of numerous satellites and payloads in geosynchronous earth orbit (GEO) and highly elliptical orbit (HEO), as well as ground-based hardware and software. SBIRS satellites and sensors are designed as a follow-on capability to the Defense Support Program (DSP) with greater flexibility and sensitivity, in addition to the ability to detect short- and mid-wave infrared signals.

SBIRS currently consists of two GEO satellites and three HEO sensors. The GEO satellites are made up of a GEO spacecraft bus, which is militarized, and radiation-hardened, providing power, altitude control, command and control, and communications subsystem for the satellite. The GEO payload consists of two infrared sensors: a scanning sensor and a step-staring sensor. The scanning sensor aboard the GEO satellite is able to continuously scan the earth to provide 24/7 global missile warning coverage and collect data that contributes to theater and intelligence missions. The step-staring sensor is designed for theater missions and intelligence areas of interest, since it contains a highly-accurate pointing and control system and is highly-agile with a fast revisit rate and high sensitivity. [1] The two HEO sensors are scanning sensors similar in nature to the GEO scanning sensors, but sensor pointing is performed by slewing the full telescope on a gimbal. Both the GEO and HEO sensors provide unprocessed data to the ground for mission processing, although the GEO sensors are able to perform on-board signal processing and transmit detected events to the ground. [2]

SBIRS GEO-1 being lowered into its shipping container in preparation for delivery

Missile Defense and Missile Warning Two of the main mission areas of SBIRS are missile warning and missile defense. SBIRS HEO and GEO sensors enable it to detect missile launches around the world, providing accurate and early warning through the Mission Control Station (MCS). SBIRS is able to detect strategic and short range ballistic missile launches, determine their flight trajectory, and provide a location for where the missile will hit. The early warning provided by SBIRS when a launch is detected gives warfighters the necessary alert to intercept the weapon as part of the OODA loop (Observe, Orient, Decide and Act). Early warning detection of missile launches and other infrared events also helps alert and protect allies and U.S. deployed troops.

Technical Intelligence The mobility and accuracy of SBIRS sensors allows them to provide a variety of data to Combatant Commanders, decision makers, and the intelligence community. SBIRS is able to characterize infrared event signatures, phenomenology, and threat performance data; and can quickly revisit areas of interest for theater missions and intelligence coverage.

Battlespace Awareness The SBIRS constellation also provides comprehensive infrared data to Combatant Commanders, Joint Task Force Commanders and other users to help increase situational awareness in order to support force protection, strike planning and other missions.

Deployment

Elements of the SBIRS program, particularly the ground-based MCS, were first used in conjunction with existing DSP legacy satellites in December 2001. [3] After several program delays, the first HEO sensor was launched into orbit in November 2006, followed by HEO-2 in June 2008. HEO-1 received its certification in December 2008. The first and second GEO satellites were launched on a United Launch Alliance Atlas V rocket from Space Launch Complex (SLC) 41 at Cape Canaveral Air Force Station, Florida in May 2011 and March 2013 respectively. As part of the follow-on production contract, HEO-3 was launched into orbit and completed its checkout in May 2015.

Current Status

The SBIRS program has been highly successful, exceeding expectations in several mission areas. Currently, HEO-4 and GEO-3 have been delivered, and GEO-4, delivered in 2014, is scheduled for launch in summer 2016. [4] Lead contractor, Lockheed Martin, has been awarded a contract to produce the GEO-5 and GEO-6 satellites. SBIRS is also currently undergoing Block 10 upgrades, which includes consolidating all SBIRS operations, including DSP and SBIRS GEO satellites and HEO sensors, into one facility. The Block 10 upgrades also consists of major software revisions, additional computer processing hardware at the MCS, and additional hardware components at each relay ground station. Block 10 upgrades are scheduled to achieve operational acceptance by August 2016. [5]

Timeline

Late 2017: Predicted launch of GEO-3.

August 2016: SBIRS Block 10 upgrades scheduled to reach operational acceptance.

Summer 2016: GEO-4 tentatively scheduled for launch.

June 2015: The HEO-4 sensor was delivered to the Air Force as part of the SBIRS follow-on contract.

May 2015: HEO-3, operating over the northern hemisphere, successfully completed its on-orbit checkout. [6]

June 27, 2014: Lockheed Martin was awarded a contract to produce the fifth and sixth SBIRS GEO missile-warning satellites.[7]

2014: HEO-3 launched into orbit.

November 2013: The GEO-2 satellite received operational acceptance from the Air Force Space Command (AFSPC).

May 2013: The GEO-1 satellite received operational acceptance from the AFSPC.

March 19, 2013: The second GEO satellite was successfully launched into orbit.

July 7, 2011: GEO-1 successfully delivered its first infrared imagery.

May 7, 2011: GEO-1 successfully launched into orbit.

March 7, 2011: The U.S. Air Force and Lockheed Martin delivered the first GEO satellite.

December 2008: HEO-1 received certification from the U.S. Strategic Command (USSTRATCOM) to operate in strategic and theatre missile warning missions. [8]

June 2008: Second HEO payload announced on-orbit.

November 2006: First HEO payload announced on-orbit.

December 2001: SBIRS Mission Control Station declared operational.

1995: SBIRS was announced as a follow-on program to the successful DSP. [9]

Sea-Based X-Band Radar (SBX)

Photo: Missile Defense Agency

Facts	
Mobility	Sea-based, mounted on a semi-submersible vessel that is able to travel at up to 8 knots
Role	Detect, track, and discriminate incoming threats and provide data to GBIs as part of the BMDS
Frequency	X-band radar
Range	Detect objects up to 4,025 km away
Status	On limited support status
Prime Contractor	Boeing, Raytheon

Photo: Missile Defense Agency

Overview

The Sea-Based X-Band Radar (SBX) is part of the U.S. Ballistic Missile Defense System (BMDS) and is designed to detect and establish precise tracking information on ballistic missiles, discriminate missile warheads from decoys and debris, provide data for updating ground-based interceptors in flight, and assess the results of intercept attempts.

The radar on the SBX is housed under the large, white radome and is considered the largest and most sophisticated phased array electro-mechanically steered X-band radar in the world, with approximately 45,000 transmit/receive modules forming the radar beam. The radar beam is capable of detecting an object the size of a baseball up to 4,025 km away. [1] The radar also uses 69,632 multi-sectional circuits to transmit, receive, and amplify signals, and the elevation at which the radar is positioned aboard the platform allows it to track objects as they fly toward, over, and away from the vessel.

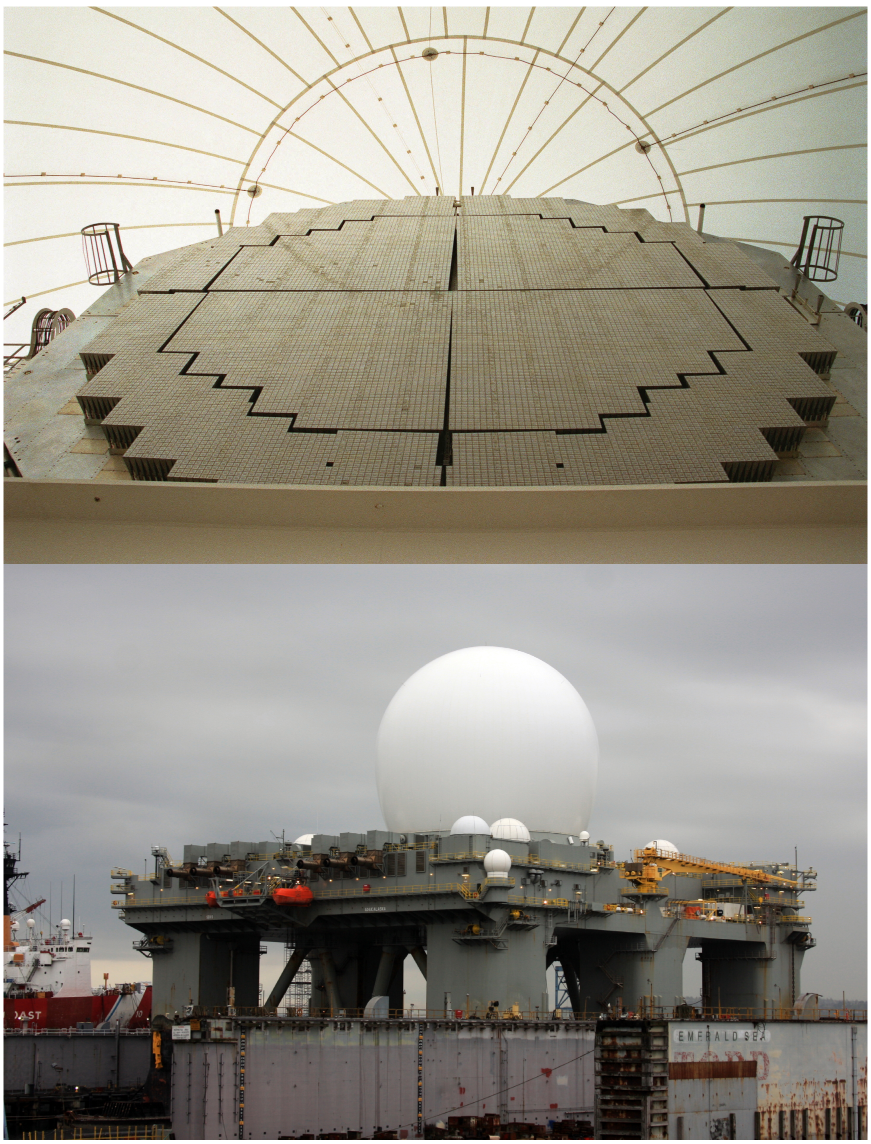
The SBX platform that houses the radar carries a crew of about 85 and includes a bridge, control rooms, living quarters, storage areas, a power generation area, a helicopter landing pad, and maintains 60-days of supplies and fuel. It also houses a command, control and communications system and an In-flight Interceptor Communication System Data Terminal that provides missile tracking and target discrimination data to interceptor missiles. [2] The platform vessel is 389 ft long with a 238 ft beam, displaces 32,690 tons, and has the ability to move at up to 8 knots. [3]

Deployment

The SBX-1 officially deployed in 2006 as part of the BMDS in the Pacific to detect and track ballistic missile threats to the U.S homeland, Hawaii and Alaska. During the mid-late 2000s, the SBX traveled around the Pacific including the waters around Hawaii and Alaska and spent time in port along the U.S. west coast. During the mid-2000s, the SBX was homeported in Adak, Alaska although it never actually visited the port or moored there. In 2009, the SBX relocated to the waters around Hawaii after North Korea threatened the island with nuclear attack.

Current Status

The SBX is currently moored in Pearl Harbor and has been on limited test support status since the beginning of FY2013. Since 2013, it has detected and tracked several targets or interceptors during GMD tests, but has not been deployed. The SBX is likely to remain on limited support status through at least 2018.



Photos: Missile Defense Agency

Timeline

January 28, 2016: During a successful GMD flight test, the SBX radar acquired and tracked a target representing an intermediate-range ballistic missile that was air-launched from a U.S. Air Force C-17 aircraft. [4]

October 2014: With the beginning of FY15, SBX was put on test and operations support status, meaning the SBX could be deployed as needed to support testing and defensive operations for the BMDS. [5]

October 2012: Beginning in FY13, SBX was placed on limited test support status in the Pacific. [6]

December 22, 2011: The SBX vessel was transferred to the Military Sealift Command (MSC), which operates and maintains the vessel, while the MDA retains responsibility for the X-band radar. [7]

December 15, 2010: The SBX radar tracked and provided real time data during FTG-06a in which an EKV was supposed to intercept a target.

June 5, 2008: SBX participated in Glory Trip 197, which detected and tracked the launch of a U.S. Minuteman III long-range missile. [8]

December 1, 2007 - April 1, 2008: SBX-1 traveled more than 4,000 nautical miles across the Pacific Ocean.

September 28, 2007: The SBX radar participated in a data collection mode during a GBI flight test intercept with the target missile launching from Kodiak Island, Alaska and the GBI from Vandenberg AFB, California.

January 9, 2006: The SBX-1, aboard the Blue Marlin, arrived in Pearl Harbor, Hawaii for maintenance, repairs, and inspections after completing its 15,000-mile journey from Corpus Christi, Texas. [9]

December 2005: The SBX-1, aboard the Blue Marlin, passed through the Strait of Magellan and into the Pacific Ocean.

July 2005: MDA officially named the semi-submersible vessel and radar system the Sea-Based X-Band Radar-1 or SBX-1. The SBX-1 also began sea trials in the Gulf of Mexico.

May 2005: The radome, the large white dome visible on top of the platform, is installed over the x-band radar to protect it from the elements.

April 2005: The X-band radar was installed on the platform in Ingleside, Texas.

January 2003: The United States government purchased a 50,000-ton, semi-submersible, self-propelled, seagoing platform to carry the radar system.

Space Tracking and Surveillance System (STSS)

Photo: Northrop Grumman

Facts	
Mobility	Deployed in low earth orbit (LEO)
Role	Track and discriminate missiles in all phases of flight and provide data for missile defense interceptors
Status	Operational in LEO
Prime Contractors	Northrop Grumman, Raytheon

Overview

The aim of the Space Tracking and Surveillance System (STSS) is to track missiles through all three phases of flight (boost, midcourse, and terminal); discriminate between warheads and decoys; transmit data to other systems that will be used to cue radars and provide intercept handovers; and provide data for missile defense interceptors to hit their target.

STSS is able to track enemy missiles against the cold background of space, particularly during the midcourse phase of flight, which is one of the biggest challenges for ballistic missile defense. STSS designers created the system to operate in conjunction with other U.S. missile defense and missile tracking systems, filling in gaps left by these systems. STSS is able to relay information to other systems, providing up-to-date information to guide missile defense interceptors and monitor possible missile threats. STSS has three main components: a wide-view acquisition sensor, a narrow-view tracking sensor, and a signal and data processor subsystem.

The wide-view acquisition sensor detects an enemy ballistic missile just after launch when it is in the boost phase and its burners are hot. The acquisition sensor provides high-resolution, horizon-to-horizon detection capability and consists of a wide field-of-view scanning refractive telescope and a short-wave infrared focal plane array.

Once the enemy missile has completed its post-boost phase and passes into its midcourse phase, the narrow-view tracking sensor picks up the threat and follows it as it travels through space. The tracking sensor includes a narrowly focused telescope that provides coverage above and below the horizon line. Even though a midcourse-phase ballistic missile does not have heat-producing rocket discharge, the narrow-view tracking sensor can detect the dim warhead.

As the wide- and narrow-view acquisition sensors and the narrow-view tracking sensor follow the enemy missile along its trajectory, the signal and data processor subsystem receives and filters the incoming data and transmits it to ground command centers such as the Command and Control, Battle Management and Communications System fielded by numerous U.S. commands around the world.

Development

MDA, NASA, and the Air Force launched the two satellites that make up the STSS-D constellation into low earth orbit from Cape Canaveral, Florida in September 2009. The two satellites orbit at 1,350 km, with a 58 degree inclination, and a 120 minute orbital period. [1] The satellites are under the control of the Missile Defense Space Development Center (MDSDC) and completed an Early On-orbit Test series in November 2010, as well as additional interoperability tests with other systems such as Aegis and various parts of the Ballistic Missile Defense System. While the STSS-D satellites provide excellent theater coverage and tracking of missile launches, as many as thirty satellites would be needed to provide worldwide coverage. [2]

Current Status

STSS-D satellites were designed as demonstration satellites with a two-year in-orbit lifespan—which has already been exceeded—and there are currently no plans to replace or launch additional satellites as part of the STSS program. Currently, MDA plans to keep the STSS-D satellites operational into the 2017 timeframe and defense contractor, Northrop Grumman Aerospace Systems was issued a contract in 2015 to provide on-orbit operations and sustainment for the STSS program.

MDA had originally planned a follow-on to STSS, the Precision Tracking Space System (PTSS), which would have used a simpler satellite that focused on cold-body missile tracking during the midcourse phase of flight, leaving the target acquisition role to SBIRS-High satellites. PTSS also planned to use a larger telescope than STSS, relying on subtle movements in space for tracking. [3] Due to fiscal restraints and sequestration, however, the Pentagon terminated PTSS in its FY14 budget request.

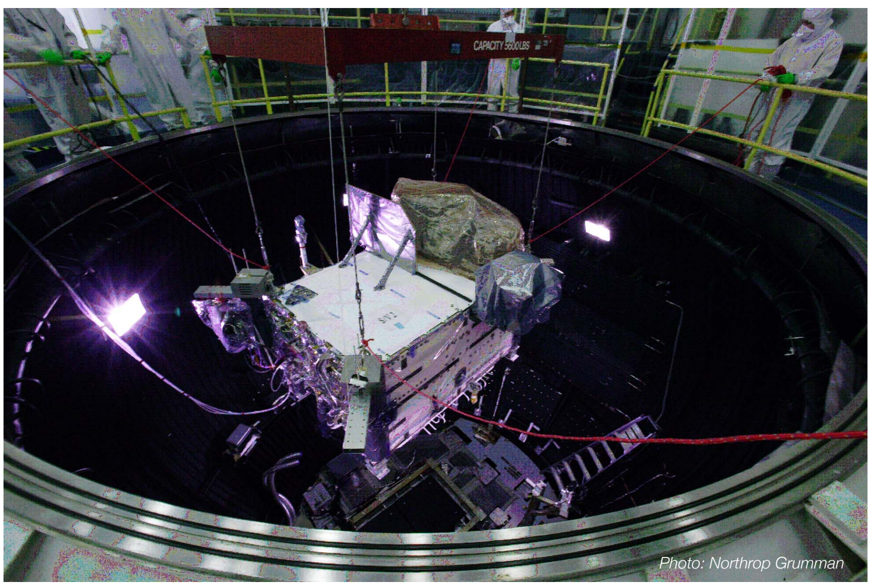


Photo: Northrop Grumman

STSS satellite undergoes a test

Timeline

February 13, 2013: MDA and the USS Lake Erie (CG 70) completed a successful intercept of a medium-range ballistic missile target over the Pacific Ocean by an SM-3 Block IA guided missile using STSS-D to detect and track the target, forwarding tracking data to the USS Lake Erie. [4]

November 3, 2010: STSS completed a series of Early On-orbit Tests that tested 127 system functionalities and demonstrated the full calibration performance of both satellites, their crosslink systems, and ability to acquire and track sensor payloads. [5]

September 17, 2010: STSS successfully demonstrated autonomous handover to the tracking sensor.

June 28, 2010: STSS spotted and observed three missile-test launches and successfully relayed data about their trajectories to observers on Earth [6]

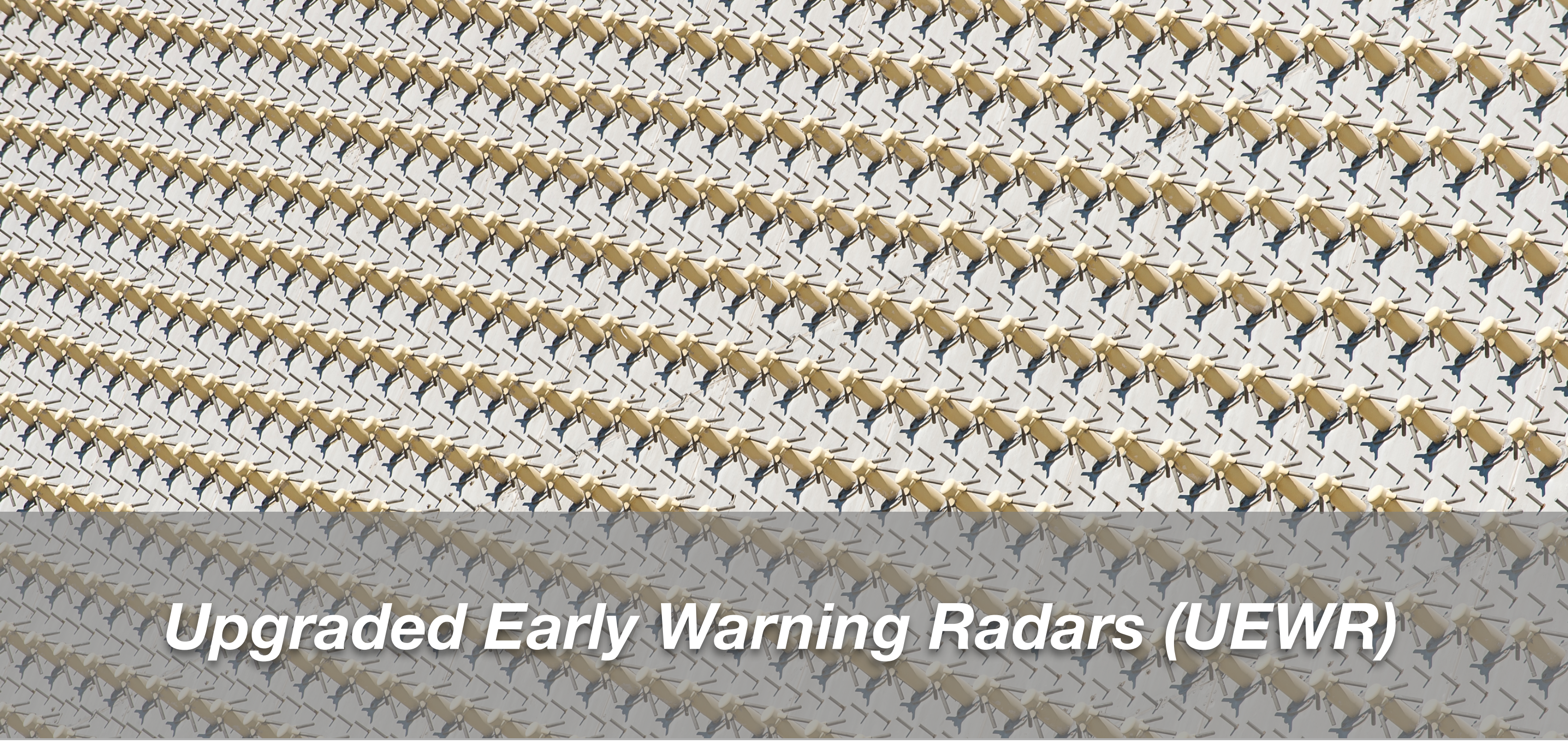
June 16, 2010: STSS-D satellites monitored an ICBM launch by the U.S. Air Force, detecting and tracking the Minuteman Missile as it flew 4,800 miles in 30 minutes before hitting its target near the Kwajalein Atoll in the western Marshall Islands. [7]

September 25, 2009: MDA, NASA, and the Air Force launched the two STSS-D satellites into low-earth orbit aboard a NASA Delta II launch vehicle from Cape Canaveral, Florida.

2001: SBIRS-Low transferred to the Missile Defense Agency where it became the Space Tracking and Surveillance System.

1996: Brilliant Eyes was transferred to the U.S. Air Force, which had been given the responsibility of building a new Space-Based Infrared System (SBIRS) to replace the old Defense Support Program (DSP).

1980s: The Space Tracking and Surveillance System (STSS) began as the Space and Missile Tracking System (SMTS) or Brilliant Eyes under the Strategic Defense Initiative Office (SDIO).



Upgraded Early Warning Radars (UEWR)

Photo: Raytheon

Facts	
Mobility	Stationary
Role	Provide detection and tracking of ballistic missiles and interceptors and classification of space objects
Frequency	Ultra High Frequency
Range	Over 4,825 km
Status	3 operational, 2 undergoing upgrades
Prime Contractor	Raytheon

Photo: Raytheon

Overview

The United States has several Upgraded Early Warning Radars (UEWR) at bases around the world and is in the process of upgrading other early warning radars to ensure they are integrated into the Ballistic Missile Defense System (BMDS) and able to provide the system with critical early warning, tracking, object classification and cueing data. The three UEWRs at Thule AB, Greenland; Beale AFB, California; and RAF Fylingdales, United Kingdom are solid-state, phased-array, all-weather, long-range radars that are designed to provide a variety of data for the BMDS. The expertise of the UEWR includes providing integrated tactical warning and attack assessment to the National Command Authority, supporting the Space Surveillance Network by classifying reentry vehicles and other space objects, and providing BMDS midcourse coverage by detecting sea-launched or intercontinental ballistic missiles, sharing real-time information with BMDS command and control nodes, tracking interceptors while they are in flight, and providing ballistic missile threat tracking data before and after interceptor launch. [1] While the UEWRs each vary slightly in their design, they all have the above abilities and are able to detect objects over 4,825 km away and operate in the Ultra High Frequency Band.

The UEWRs are strategically located at bases around the United States and at allied bases. The positioning of these radars are designed to provide the U.S. with complete coverage and allow for early warning detection of any incoming ballistic missile threat regardless of the point of origin.

Installations

Thule Air Base, Greenland (Denmark)

The Thule Ballistic Missile Early Warning Radar System (Thule BMEWR) is located at Thule Air Base in northwestern Greenland. Thule AB is the northernmost installation of the U.S. Department of Defense and is 750 miles north of the Arctic Circle, and 947 miles south of the North Pole. [2] Positioned between Europe and North America, Thule AB is in a strategic location to monitor and track ground-launched ballistic missile threats on trajectories over the North Pole from countries such as Russia or North Korea, and submarine-launched missiles from the Arctic and North Atlantic Oceans. The Thule BMEWR is a 2-faced phased array radar and is operated by the 12th Space Warning Squadron.

RAF Fylingdales, United Kingdom

The Fylingdales Ballistic Missile Early Warning System (Fylingdales BMEWS) is located at the Royal Air Force Fylingdales in the United Kingdom. The Fylingdales Solid State Phased Array (SSPAR) has three faces and uses changes in electrical phase to steer the radar beam and continually search out to 4,825 km for incoming objects or missiles. The Fylingdales BMEWS is designed to detect and track ballistic missiles headed towards the United States mainland and United Kingdom from the Middle/Near East.

Clear Air Force Station, Alaska

The Clear AFS Ballistic Missile Early Warning System (BMEWS) is one of the three original BMEWS sites. The radar system is operated by the 13th Space Warning Squadron and detects, tracks, and identifies over 9,500 man-made objects orbiting the Earth. The radar also provides total coverage of the North American continent in the event of ground-based or sea-launched ballistic missile attack. Since FY12, the Solid-State Phased Array Radar System (SSPARS) has been one of two radar systems undergoing upgrades to further integrate it into the BMDS, and these upgrades are expected to be completed in FY16.

Beale Air Force Base, California

The early warning radar at Beale Air Force Base has been part of the United States BMEWS since 1979 when the 7th Missile Warning Squadron brought the Phased Array Warning System (PAVE PAWS) Radar site to Beale. [6] Since 1979, the radar site has undergone hardware and software upgrades to its electronic and computer systems. The Beale AFB BMEWS has two faces and is designed to detect and track land and sea-launched ballistic missiles headed towards the United States mainland from the Pacific.

Cape Cod Air Force Station, Massachusetts

The PAVE PAWS early warning radar at Cape Cod AFS was activated in 1980 and is operated by the 6th Space Warning Squadron. The radar site is designed to guard North America's East Coast against sea-launched and intercontinental ballistic missiles, with a secondary mission of tracking Earth-orbiting objects such as the International Space Station, the Space Shuttle, any object that deviates from its known orbit, or any new orbiting objects. Since FY13, the Cape Cod AFS radar site has been undergoing upgrades and is set to be competed in 2017.

Thule Timeline

March 2011: U.S. defense contractor Raytheon completed all system requirements and testing of the UEWR system. [3]

March 2008: The construction phase of the UEWR was completed at Thule AB.

April 2006: The Missile Defense Agency (MDA) awarded Raytheon the contract for the UEWR at Thule.

May 2004: Denmark agreed to allow the Thule radar to be upgraded to the UEWR.

June 1987: The old 12 SWS radar was upgraded to a solid-state, phased-array system making operation more efficient and effective. [4]

1960: A 12 SWS radar system was constructed at Thule AB and integrated into the larger Ballistic Missile Early Warning Radar (BMEWR) network.

1951-1953: Thule AB was built under the code name Operation Blue Jay and was completed in 1953 serving as a NATO listening post during the Cold War.

RAF Fylingdales, UK Timeline

2007: The UEWR underwent testing and acceptance following upgrades.

2003: Following an agreement with the British, the U.S. made upgrades to the SSPAR to improve the radar's missile tracking capabilities.

1988/1989: U.S. contractor, Raytheon, and U.K contractor, John Laing Ltd, were awarded contracts for the radar and buildings for the new radar system. [5]

May 22, 1986: The U.S. and the U.K. announced an agreement to modernize the old mechanical radar system into a new phased array radar system.

1963: RAF Fylingdales was first declared operational as one of 3 radar sites in the BMEWS to provide radar coverage for the East coast of the United States and the United Kingdom

Clear Air Force Station, Alaska Timeline

2016: The UEWR is due to be completed and operational during FY16.

September 2012: Raytheon was awarded a $125.3m contract by MDA and USAF to upgrade the EWR system. [7]

1981: The radar at Clear AFS was upgraded to a AN/FPS-123 Solid-State Phased Array Radar System.

September 1961: The radar deployed as part of the BMEWS achieved full operational capability.

Section 4 - International Cooperation on Missile Defense

The Japan Maritime Self-Defense Force guided-missile destroyer JS Kirishima (DDG 174) and the guided-missile cruiser USS Lake Erie (CG 70) observe morning colors at Joint Base Pearl Harbor-Hickam during Rim of the Pacific (RIMPAC) 2014

Photo: U.S. Navy

4.1 International Cooperation Overview

The United States has a long history of international cooperation in the realm of missile defense, dating back to its early Nike missile defense system. International cooperation on missile defense helps to reduce financial burdens, ensure interoperability and adaptability, and build military and diplomatic partnerships.

The legal foundation for many modern cooperative arrangements is a "BMD Framework Partnership," which is a bilateral agreement or memorandum of understanding that expresses mutual commitment to BMD and BMD cooperation. These bilateral partnerships establish periodic meetings and exchanges of information, but no specific cooperative commitments —any further cooperative activities are the subject of later agreements or arrangements. Current U.S. BMD Framework Partners are Australia, Czech Republic, Denmark, Italy, Japan, and the United Kingdom. Most of these partnerships have been expanded upon to include technical and technological missile defense collaboration.

Cooperative development and deployment of missile defense systems helps to reduce the financial burden placed on the developing country and its defense industry and forms lasting partnerships. The history of cooperation on missile defense between the United States and Japan dates back to the deployment of the Nike-J missile in the 1960s and since then the two countries cooperated on numerous projects including the Patriot PAC-2 and the SM-3 Block IIA interceptor. The United States and Israel are also long-time partners on missile defense projects such as the Arrow system, David's Sling and Iron Dome.

International cooperation on missile defense is essential to ensure interoperability and successful communications between allied nations. The United States, NATO, and European nations routinely participate in missile defense exercises such as the Maritime Theater Missile Defense Forum, which held a large scale exercise in November 2015. This exercise included personnel, planes and ships from nine countries, and demonstrated over 26 successful missile intercepts, highlighting information sharing between the ships of the allied nations.

Missile defense cooperation during the research and development phase of a new system also helps to field systems that are easily adaptable to the individual preferences of numerous countries. The Medium Extended Air Defense System (MEADS) was jointly developed by the United States, Germany, and Italy to meet International Common Operational Requirements and its software can be tailored to fit each country's needs and it is interoperable with a variety of external interfaces.

Cooperation among nations on issues concerning missile defense also contributes to overall diplomatic and military partnerships. The U.S. relationship with Arabian Gulf countries and members of the Gulf Cooperation Council (GCC) has flourished through cooperation on missile defense in the region, which is designed to protect against Iranian ballistic missiles. These countries have forged lasting partnerships over common interests and have create avenues for continued cooperation such as the U.S. Central Command Integrated Air and Missile Defense Center of Excellence in Abu Dhabi.


Photo: U.S. Navy

The Arleigh Burke-class guided missile destroyer USS Ross (DDG 71) takes part in a ship formation to begin At Sea Demonstration 2015


Photo: Mtlarsen, Creative Commons

Denmark

Current Contributions: BMD Framework Partner; Thule Upgraded Early Warning Radar; RDT&E Cooperative Project.

Future Contributions: Pledged BMD upgrade to Iver Huitfeldt-class frigates' SMART-L radar systems.

France

Current Contributions: University to University Research; Cooperative R&D Agreement, SAMP/T theater BMD system.


Photo: MBDA


Photo: AFP

Germany

Current Contributions: 12 PAC-3 batteries , 12 PAC-2 batteries, hosts C2BMC Command and Control at Ramstein AFB, hosts U.S. PAC-3 Batteries with the 10th U.S. Army Air and Missile Defense Command.

Future Contribution: Medium Extended Area Defense System (MEADS).

Italy

Current Contributions: BMD Framework Partner, SAMP/T theater BMD system.

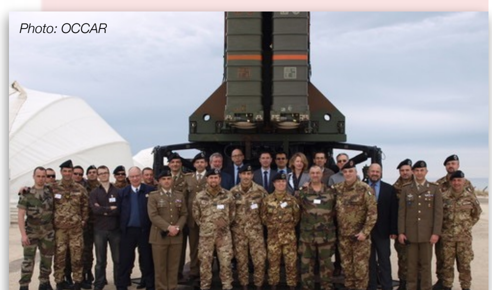


Photo: OCCAR


Photo: U.S. Air Force

Netherlands

Current Contributions: PAC-3 batteries, PAC-2 Batteries, Air-defense and Command Frigates (LCF) equipped with upgraded SMART-L radar systems.

Poland

Current Contributions: Agreed to host Aegis Ashore (EPAA Phase 3).

Future Contributions: Considering Patriot or Medium Extended Area Defense System (MEADS).


Photo: Reuters

Photo: NATO

Romania

Current Contributions: Hosting Aegis Ashore Site, Phase 2 of the European Phased Adaptive Approach.

Spain

Current Contributions: 6 PAC-2 batteries, hosts 4 U.S.Aegis BMD Ships at Rota, Phase 1 of the European Phased Adaptive Approach.


Photo: U.S. Navy


Photo: Raytheon

Turkey

Current Contributions: AN/TPY-2 radar host as part of EPAA Phase 1, University to University Research.

United Kingdom

Current Contributions: Fylingdales Upgraded Early Warning Radar, Joint Project Arrangements for Cooperative Projects.

Future Contributions: The UK's National Security Strategy, released in November of 2015, called for a new ground-based BMD radar and the investigation into the potential of Type 45 Destroyers to operate in a ballistic missile defense role.


Photo: GOV.UK

The Middle East

Photo: AFP

Israel

Current Contributions: Arrow Deployed, Arrow System Improvement Program; development of David's Sling Weapon System; Iron Dome.

Photo: Military Edge

Kuwait

Current Contributions: PAC-2

Future Capabilities: On July 20, 2012, the Administration notified a potential sale of 60 PAC-3 missiles and 20 Patriot launching stations. On December 31, 2013, DOD said Lockheed Martin would deliver 14 of the missiles and seven launcher modification kits by June, 2016.

Photo: Green Stylo

Qatar

Current Contributions: Missile defense discussions.

Future Capabilities: In July 2014, Qatar announced that it would be purchasing 10 PAC-3 batteries, its first acquisition of a missile defense system.

Photo: Military-Today.com

Saudi Arabia

Current Contributions: Missile defense discussions, PAC-2.

Future Capabilities: In July, DSCA announced a potential sale of 600 PAC-3 interceptors to Saudi Arabia. Saudi Arabia has also contracted to upgrade several hundred of its older interceptors.

Photo: Lockheed Martin

United Arab Emirates

Current Contributions: The UAE is the first non-U.S. operator of the THAAD system, and the only GCC country to deploy Patriot PAC-3.

Future Capabilities: The UAE may also be interested in acquiring Patriot MSE interceptors for its current Patriot batteries.

The Pacific

Australia


Photo: Royal Australian Air Force

Current Contributions: BMD Framework Partner; R&D Cooperative Project. Jindalee Operational Radar Network (JORN), an over-the-horizon radar (OTHR) network that monitors air and sea movements.

Future Contributions: On June 13, 2014 President Barack Obama and Australian Prime Minister Tony Abbott discussed plans to enhance cooperation on the ballistic missile defense system.


Photo: U.S. Navy

Japan

Current Contributions: 4 Kongo Class Aegis BMD Ships, 6 PAC-3 Battalions, hosting 2 AN/TPY-2 Radars, cooperating on the Standard Missile-3 block IIA.

Future Capabilities: Japan is considering the purchase of THAAD as well as up to 2 Aegis Ashore systems.

Republic of Korea


Photo: U.S. Army

Current Contributions: Patriot PAC-2 and PAC-3 batteries, Israeli-made Green Pine land-based radar systems, and three KDX-III Class Aegis Destroyers equipped with SPY-1D(V) radar.

Future Contributions: South Korea and the United States have entered into formal negotiations to deploy a THAAD system to the ROK.


U.S. and Japanese Aegis vessels sail in formation during a joint naval exercise in the Pacific

Section 5 - Future Capabilities

In February of 2010, the Airborne Laser Testbed destroyed a threat representative short-range ballistic missile during a test

Photo: Missile Defense Agency

5.1 Hypersonic Missiles

Overview Hypersonic missiles are specifically designed for increased survivability against modern ballistic missile defense systems. These missiles are capable of delivering conventional or nuclear payloads at ultra-high velocities over long ranges. Hypersonic missiles are delivered in two ways: (1) they can be fired from the last stages of Intercontinental Ballistic Missiles (ICBM) or Submarine-Launched Ballistic Missiles (SLBM) and skip along the top of the atmosphere using specialized jet engines to accelerate to hypersonic speeds; or (2) they can be launched independently or released from a bomber—similar to cruise missiles—before accelerating to ultra-high speeds.

In contrast to conventional Reentry Vehicles (RV) that travel at supersonic speeds (between Mach 1 and Mach 5), hypersonic weapons travel along the edge of space and accelerate to between Mach 5 (around 3,800 mph) and Mach 10 (over 7,500 mph). While conventional ballistic missiles are launched at steep trajectories that inhibit speed during the high friction of launch and reentry, hypersonic missiles glide atop the atmosphere while engaging specialized jet engines to perpetually accelerate up to hypersonic speeds.

This ability to travel at ultra-high velocity is the primary appeal of hypersonic missiles because it extends their range and allows them to bypass modern layered missile defenses. [1] Hypersonic missiles are also capable of maneuvering in flight, allowing them to evade missile defense tracking systems and interceptors. This is in contrast to conventional RVs, which descend through the atmosphere on a predictable ballistic trajectory that can be tracked and intercepted by modern missile defense systems.

A rendering of a hypersonic vehicle

Nations Pursuing Hypersonic Missiles

The United States, China, and Russia are designing and testing hypersonic missiles. The U.S. is pursuing hypersonic missiles to deliver conventional payloads, while China and Russia plan to equip hypersonic missiles with conventional as well as nuclear warheads.

The United States The U.S. has invested in research and development of a hypersonic missile called the Advanced Hypersonic Weapon (AHW), which uses boost glide technology to propel warheads with conventional—rather than nuclear—payloads. Hypersonic boost glide technology uses a different type of propulsion known as Supersonic Combustion Ramjet or "scramjet." Scramjet engines take in oxygen from air passing through the engine to propel the vehicle, requiring limited onboard fuel reserves. This allows AHW to achieve hypersonic speeds by maintaining thrust while reducing the weight of fuel the missile must carry. In contrast, ballistic missiles rely solely on an onboard fuel tank, which adds weight and slows the vehicle.

Washington plans to use AHW for "Prompt Global Strike," which would allow the U.S. to launch a conventional hypersonic strike against targets anywhere on the planet in less than one hour. During a test in 2011, AHW was launched from the Pacific Missile Range Facility in Kauai, Hawaii, to the Reagan Test Site on the Marshall Islands. The glide vehicle successfully struck a target that was located 3,700 km away, demonstrating the long-range and high precision of the AHW. [2]

China Since 2014, China has carried out several tests of its Hypersonic Glide Vehicle (HGV) called the DF-ZF. The DF-ZF is launched during the last stage of a missile and can reach nearly 7,500 mph (Mach10), as well as maneuver to avoid missile defenses and zero in on targets. This weapon can be configured to carry a nuclear or conventional warhead and China claims it is precise enough to attack ships at sea. The DF-ZF is scheduled to be operational as early as 2020. [3]

Russia Russia has been designing and testing the YU-71 hypersonic missile. The YU-71 can travel at speeds of up to 7,000 mph, is highly maneuverable, and can carry conventional or nuclear warheads. It has been tested several times since February 2015 and is scheduled to be deployed between 2020 and 2025. Russia is also developing a stealth bomber called the PAK DA that is capable of carrying hypersonic cruise missiles. [4]

5.2 Future Systems

As technology allows new threats to evolve, the options for fielding a robust missile defense to protect the U.S. homeland, our deployed forces and allies also continue to broaden. Approaches thought to be infeasible decades ago are moving quickly into the realm of the possible, even practical. While some initiatives look to harness revolutionary technologies such as directed energy, others can be done by enhancing currently deployed systems with existing technology.

MDA's Airborne Laser (ABL) was successful in a lethal intercept experiment in 2010

Boost Phase Missile Defense

Boost phase missile defense entails the destruction of an enemy missile during the earliest stages of its flight, while it remains within the Earth's atmosphere. A viable boost phase defense has long been considered the "holy grail" of BMD, as boosting missiles are much slower and easier to track than missiles during the midcourse or terminal stage, which makes them more vulnerable to interception. Boost phase defense also overcomes the challenges of discriminating between lethal warheads and debris, as the missile is largely intact at this stage and has not had the opportunity to deploy decoys.

The main challenges for boost phase defense include the short window of opportunity between launch detection and the missile entering the midcourse phase. Kinetic interceptor systems must be placed either very close to a missile's launch point or be fast enough to cover the necessary distance before the missile enters midcourse. This has proven problematic from both a geographic and engineering standpoint. The small window of opportunity also requires a dense system of early warning sensors to ensure the maximum time possible to conduct an interception.

Boost phase defense is not a new concept and featured prominently in the Strategic Defense Initiative (SDI), launched by President Reagan in 1983. Defense Secretary Caspar Weinberger envisioned a constellation of orbiting interceptors that would intercept Soviet ICBMs in the boost phase to prevent the Multiple Independent Reentry Vehicles (MIRVs) and countermeasures from deploying. The Missile Defense Act of 1991, however, forced an end to serious exploration of space-based systems as Congressional pressure limited research to terrestrial systems that fell within limitations imposed by the Anti-Ballistic Missile (ABM) Treaty.

Subsequent discussions of boost phase missile defense in the 1990's centered on placing a high-speed air-launched rocket on either a bomber or Unmanned Aerial Vehicle (UAV) for theater missile defense missions. The last of these efforts in the 1990's was a joint U.S.-Israeli effort to place a Moab interceptor on an Israeli UAV, but the program was cancelled in 1999. In 1996, the Department of Defense invested in the Airborne Laser (ABL), which was intended to deploy a megawatt-class chemical laser aboard a 747 aircraft to destroy the skin of a missile during its boost phase. In 2004, the Missile Defense Agency (MDA) tested the ABL's laser on the ground and throughout 2010, the MDA Airborne Laser Test Bed (ALTB) proved the capability to destroy missiles in their boost phase. However, practical concerns about providing support aircraft to continuously deploy a 747 in enemy airspace eventually ended the project.

The long loiter times of UAVs make them the ideal systems to deploy advanced sensor capabilities and to potentially deploy future directed energy (laser) based systems for boost phase missile defense. Further development of solid-state lasers may be required to make such a system viable, as the ALTB had to be housed in a 747 due to the weight associated with its chemical laser. Sea-based interceptors could also be used in boost phase intercepts as long as the associated ships were deployed sufficiently close to adversary missile sites. The SM-3 Block IIA, co-developed with Japan and tested in June 2015, could also be outfitted for boost phase defense with investment in a lighter kill vehicle that would allow the system to reach the intercept speeds necessary to hit an accelerating missile.

Directed Energy

Directed energy weapons are those that use high-energy lasers or high-power microwaves to achieve their ends. High-powered microwave systems emit electrically-powered pulses of microwave radiation at a wide angle to negate threats, while high-energy lasers direct highly focused beams of lower-powered energy using chemical fuel or electric power at their target. To date, most research and development in directed energy has focused on laser-based systems that use chemical, solid-state, or free electron lasers to destroy incoming threats.

Chemical lasers use the energy-liberating reaction of a mix of chemicals in their gaseous states to create atoms and ions in excited states that can be focused on a point by a lasing medium. The reactions must take place at very low temperatures, which requires a series of vacuum pumps, chemical management systems, and low-pressure reaction chambers. All of this equipment takes up a significant amount of space and requires toxic chemicals, limiting the number of platforms that can house chemical lasers. Chemical lasers also require a significant amount of chemical feedstock to equip the war fighter with a large enough magazine to take multiple shots. The Airborne Laser Test Bed used a chemical oxygen-iodine laser (COIL), which has been the most developed chemical laser concept, to produce the megawatts of power required for boost phase missile intercepts.

In contrast to chemical lasers, solid-state lasers (SSL) use electrical energy and ceramic or glass-like solid as a lasing media. The shape of the lasing media differentiates the three types of SSLs: bulk lasers, fiber lasers, and thin-disk lasers. Bulk and thin-disk lasers both use glass or crystalline slabs of various thickness coated with elements whose excited ions produce the beam. Fiber lasers use strands of fibers, much like optical fibers, coated in similar elements to slab style lasers. Outputs of multiple SSLs can also be combined to generate a single beam with a higher output. While these systems require less space to house components than chemical lasers, they have yet to produce sufficient power in the beams to pierce ballistic missile casing.

The Navy has worked on developing free electron lasers (FEL), which use beams of electrons accelerated to nearly the speed of light in rings and powerful magnets to then “wiggle” the electron beams into a focused beam of laser photons. These beams can be tuned to different wavelengths to adjust to different atmospheres, making them adaptable in the maritime environment. The Navy hopes to produce a multi-megawatt FEL by the 2020’s. To accomplish that and turn an FEL into a deployable system, work will need to be done to increase the efficiency of its energy use, regulation of thermal loads and shielding of systems of personnel.

Directed energy systems are being developed and demonstrated by the Army, Navy, and Air Force and are looked at as potential weapon systems for targeting missiles during the boost phase of flight. Most current laser-based weapons are in the 10s of kilowatts of power and are demonstrated at shorter ranges for surface and low-altitude operations where they are meeting or exceeding requirements and helping researchers develop a concept of operations (CONOPS) for future systems. [1] National laboratories and industry leaders are also working to develop a laser-based system able to be outfitted on planes or UAVs.

While directed energy systems are showing great promise, they face several technological challenges including generating enough power to cover longer distances, controlling the laser beam, developing an effective platform on which to deploy the system, and increasing the lethality of the booster. [2] These challenges need to be further explored and overcome to field an effective directed energy system.

Space-Based Tracking and Discrimination

Space-based radar systems provide a potential solution to the geographic problems associated with terrestrial radars. By operating from the ultimate high ground, they can cover significantly more of the globe than any single terrestrial radar. A future constellation of satellites could provide birth-to-death tracking of adversary missiles, making the task of discrimination easier by providing a picture of the whole track of its flight. Spaced-based systems also do not require negotiating basing agreements with foreign countries.

The United States has employed space-based early warning systems since the 1950s and continues to develop and deploy new technologies today. Recently the U.S. has looked to partnerships with the commercial sector to base sensors on commercial satellites, controlling costs and reducing the vulnerability of U.S. defense satellites to anti-satellite (ASAT) weapons.

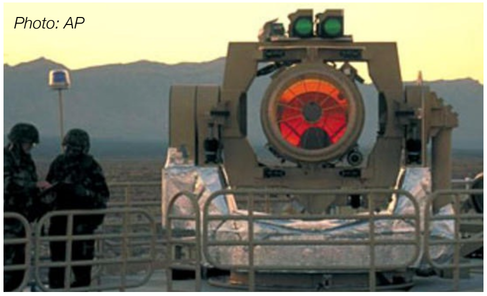


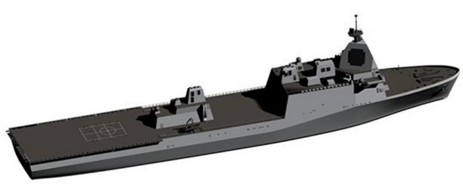
Photo: AP

High Energy Laser Mobile Demonstrator (HEL MD) This U.S. Army system is being developed to provide force protection against rockets, artillery, cruise missiles and UAVs. The system was successfully tested in 2013, downing more than 150 targets, including mortar shells and UAVs in flight. During testing, the HEL MD also showed an ability to operate in inclement weather, including rain, high wind and fog.

High Energy Liquid Laser Air Defense System (HELLADS) The HELLADS is a Defense Advanced Research Project Agency (DARPA) project to develop a 150 kW, solid-state laser weapon that is ten times smaller and lighter than current lasers with similar power. The smaller size of the laser would enable it to be integrated onto tactical aircraft to reduce threats from the ground. In May 2015, HELLADS moved from laboratory development into field testing at White Sands Missile Range in New Mexico.


Photo: DARPA

Photo: Huntington Ingalls



LPD Based Ballistic Missile Defense Ship (BMD Ship) Huntington Ingalls Shipbuilding has developed a conceptual redesign of the LPD-class hull to house a 30-35 foot multi-faced S-Band radar for mobile, large area missile tracking and discrimination. Certain configurations of the ship would also facilitate launch tubes for interceptors, directed energy weapons, and a rail gun.

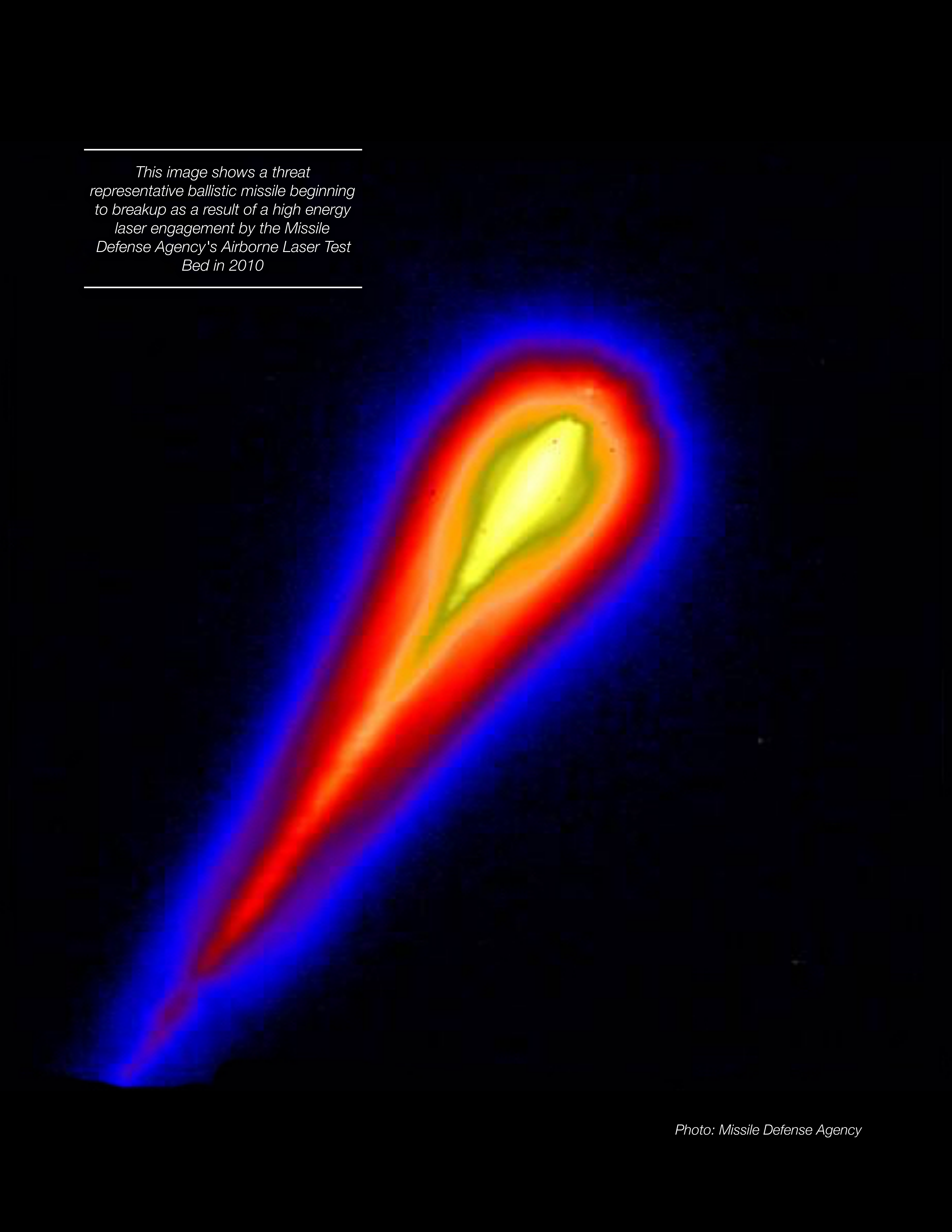
Laser Weapon System (LaWS) The U.S Navy's LaWS is designed to address multiple threats using a range of options, from non-lethal, optical "dazzling" and disabling, to lethal destruction of targets. It could prove to be a pivotal asset against "asymmetric threats," including UAVs. In summer 2014, LaWS was mounted on the USS Ponce for further testing and successfully engage its targets, leading to the system's deployment in the Persian Gulf. In the future, the Navy hopes to expand the power available to lasers to allow them to counter anti-ship ballistic missiles.


Photo: U.S. Navy


Photo: SES

The USAF Commercially Hosted Infrared Payload (CHIRP) satellite

Space-Based Kill Assessment (SKA) SKA is joint project between MDA and Johns Hopkins University Applied Physics Laboratory to develop a network of small sensors hosted on commercial satellites. The sensors help to determine whether or not a threatening missile has been eliminated by doing a "kill assessment." Sensors performing a "kill assessment" help to reduce the number of interceptors fired to ensure that any incoming missile would be eliminated before reaching its target. [3] The network of SKA sensors is projected to be deployed by 2017 and will be placed in orbit according to launch plans of the commercial host.



This image shows a threat representative ballistic missile beginning to breakup as a result of a high energy laser engagement by the Missile Defense Agency's Airborne Laser Test Bed in 2010

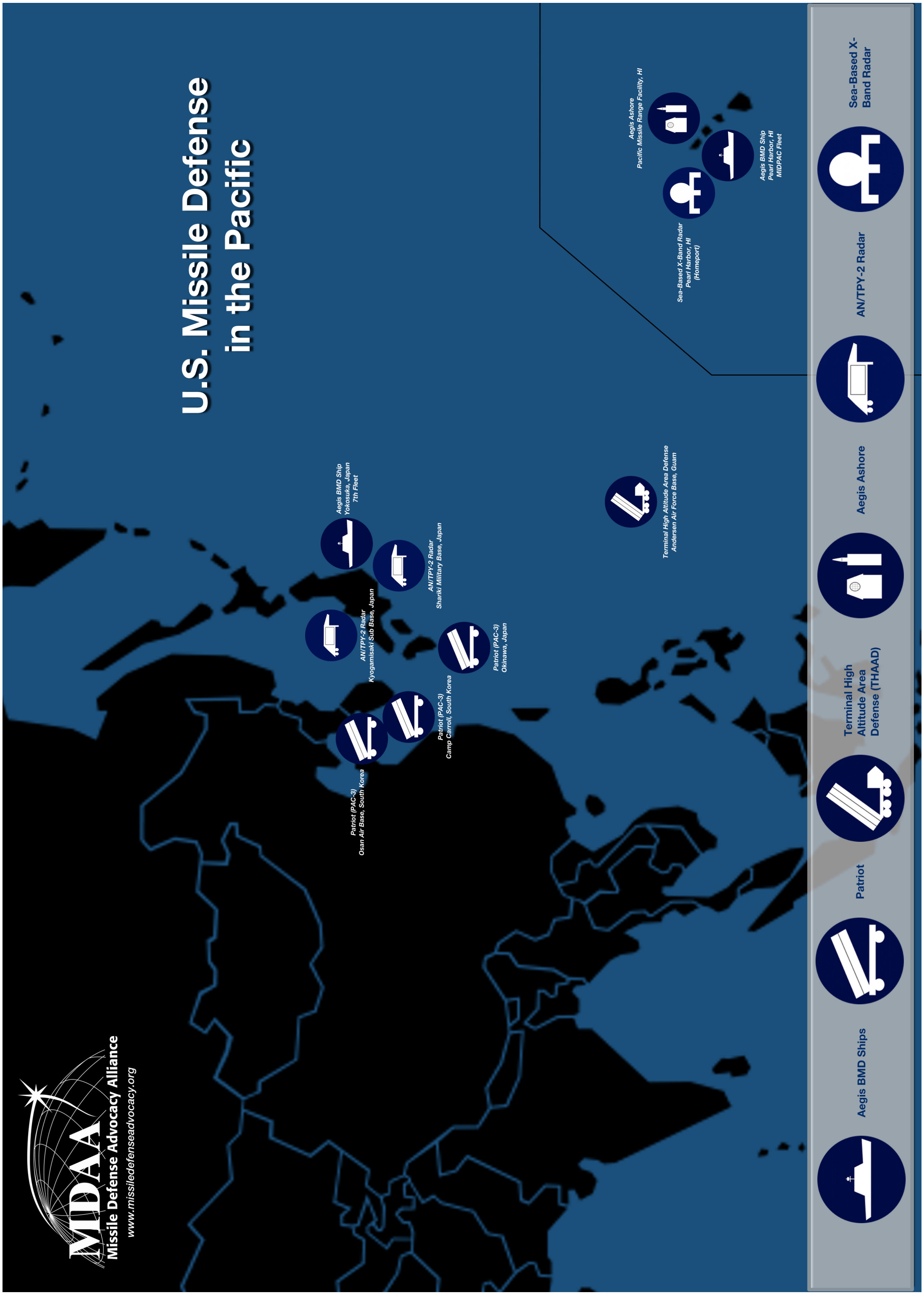
Photo: Missile Defense Agency

ACRONYMS	
ABM	Anti-ballistic Missile
ASCM	Anti-Ship Cruise Missile
BMDS	Ballistic Missile Defense System
C2BMC	Command, Control, Battle Management and Communications
EKV	Exoatmospheric Kill Vehicle
EOR	Engage on Remote
EPAA	European Phased Adaptive Approach
GBI	Ground Based Interceptor
GEO	Geosynchronous Earth Orbit
GMD	Ground-based Midcourse Defense
HEO	Highly Elliptical Orbit
HGV	Hypersonic Glide Vehicle
ICBM	Intercontinental ballistic missile
IRBM	Intermediate Range Ballistic Missile
JLENS	Joint Land Attack Cruise Missile Defense Elevated Netted Sensor System
LEO	Lower Earth Orbit
LOR	Launch on Remote
LRDR	Long Range Discrimination Radar
MARV	Maneuverable Reentry Vehicle
MDA	Missile Defense Agency
MEADS	Medium Extended Air Defense System
MIRV	Multiple Independently Targetable Re-entry Vehicle
MOKV	Multi-object Kill Vehicle
MRBM	Medium Range Ballistic Missile
NATO	North Atlantic Treaty Organization
PAC-3	Patriot Advanced Capability-3
RKV	Redesigned Kill Vehicle
SBIRS	Space-Based Infrared System
SBX	Sea-Based X-Band Radar
SDI	Strategic Defense Initiative
SDIO	Strategic Defense Initiative Organization
SLBM	Submarine Launched Ballistic Missile
SLV	Satellite Launch Vehicle
SM-2, SM-3, SM-6	Standard Missile-2, Standard Missile-3, Standard Missile-6
SRBM	Short Range Ballistic Missile
STSS	Space Tracking and Surveillance System
TBMD	Theater Ballistic Missile Defense
THAAD	Terminal High Altitude Area Defense
UEWR	Upgraded Early Warning Radars

Key States with BMD Capabilities

STATE	MILITARY INSTILLATION	MILITARY PRESENCE
Alaska	Fort Greely, Clear Air Force Station	49th Missile Defense Battalion, 213th Space Warning Squadron
California	Beale Air Force Base, Los Angeles Air Force Base, Naval Base San Diego, Vandenberg Air Force Base	Detachment 1, 100th Missile Defense Brigade; U.S. Third Fleet; 7th Space Warning Squadron
Florida	Naval Station Mayport	U.S. Naval Forces South
Hawaii	Joint Base Pearl Harbor-Hickam, Pacific Missile Range Facility	94th Army Air and Missile Defense Command; U.S. Third Fleet
Maryland	Aberdeen Proving Ground	
Massachusetts	Cape Cod Air Force Station	6th Space Warning Squadron
North Carolina	Fort Bragg	108th Air Defense Artillery Brigade
Oklahoma	Fort Sill	31st Air Defense Artillery Brigade; 30th Air Defense Artillery Brigade
Texas	Fort Bliss, Fort Hood	32nd Army Air and Missile Defense Command; 69th Air Defense Artillery
Virginia	Naval Station Norfolk	Fleet Forces Command


MDAA
Missile Defense Advocacy Alliance
www.missiledefenseadvocacy.org
U.S. Missile Defense in Europe and the Middle East
Upgraded Early Warning Radar Thule, Greenland
Upgraded Early Warning Radar Fylingdales, United Kingdom
Patriot PAC-3 Battalions Germany
Aegis Ashore EPAA Phase 3 (2018) Poland
Aegis Ashore EPAA Phase 2 (2015) Romania
AN/TPY-2 Turkey
Aegis BMD Ship EPAA Phase 1 Rota, Spain
Aegis BMD Ships Mediterranean (Deployed) 6th Fleet
AN/TPY-2 Radar Israel
Patriot PAC-3 Kuwait
AN/TPY-2 Arabian Gulf
Patriot PAC-3 UAE
Patriot PAC-3 Bahrain
Patriot PAC-3 Qatar
Aegis BMD Ships Persian Gulf (Deployed) 5th Fleet
Aegis Ashore
Aegis BMD Ships
Patriot
Upgraded Early Warning Radar
AN/TPY-2 Radar


U.S. Missile Defense
in the Pacific
Aegis BMD Ship
Yokosuka, Japan
7th Fleet
AN/TPY-2 Radar
Shariki Military Base, Japan
AN/TPY-2 Radar
Kyogamisaki Sub Base, Japan
Patriot (PAC-3)
Okinawa, Japan
Patriot (PAC-3)
Camp Carroll, South Korea
Patriot (PAC-3)
Osan Air Base, South Korea
Terminal High Altitude Area Defense
Andersen Air Force Base, Guam
Aegis Ashore
Pacific Missile Range Facility, HI
Aegis BMD Ship
Pearl Harbor, HI
MIDPAC Fleet
Sea-Based X-Band Radar
Pearl Harbor, HI
(Homeport)
Aegis BMD Ships
Patriot
Terminal High Altitude Area Defense (THAAD)
Aegis Ashore
AN/TPY-2 Radar
Sea-Based X-Band Radar
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