The Status of U.S. Ballistic Missiles Defense Programs

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Abstract

The United States is not only at the forefront of the research and development of ballistic missile defense (BMD)systems, but also its deployment. It focusses on two areas of application, namely, on the one hand Homeland Defense to protect the US mainland, and on the other, protection of U.S. overseas regions, forward-based troops, and allied territories. In general, limited and reliable missile defense can be a legitimate tool to protect specific areas, or regions from very distinct threats. However, it can also result in an increased threat perception by others because of its multiple uses. It could also have possible spillover effects, such as the deployment disrupting military balances of power, causing misunderstandings in turn. In this context, China and Russia have both been raising such concerns for years regarding U.S. global missile defense architecture and deployment plans. This article reviews the current status of the four main U.S. BMD programs: the Ground-Based Midcourse Defense (GMD); the naval Aegis Ballistic Missile Defense system deployed onboard ships and ashore; the land-based Theater High Altitude Area Defense (THAAD); and the Patriot PAC-3 tactical BMD system. To date, no major area defense system is functional, nor has any been proven effective. Yet, U.S. BMD programs aggravate great power competition, forcing nuclear weapons modernization and threatening existing, as well as future, arms control efforts.

Introduction

The United States is at the forefront of research and development, and the deployment of Ballistic Missile Defense (BMD) systems, focusing on two areas; the Homeland Defense of U.S. mainland, and the protection of U.S. regions overseas, forward based troops, and allied territories. For these purposes, there are currently four main BMD programs; namely, the *Ground-Based Midcourse Defense* (GMD), the naval *Aegis Ballistic Missile Defense* system deployed onboard ships and ashore, the land-based *Theater High Altitude Area Defense* (THAAD) and the *Patriot* PAC-3 tactical BMD system. Since the mid-1980s the U.S. has spent more than US$189 billion on BMD programs according to data from the U.S. *Missile Defense Agency* (MDA).[1] But up to now, neither a functional and proven major area defense system has been established, nor can these systems, which has a very limited number of strategic interceptors each, can mitigate a realistic threat to the U.S. mainland.

Homeland Defense

To counter long-range ballistic missiles threats to the continental U.S., a missile defense system requires wide-range sensor coverage. For this purpose the U.S. is operating different sensor assets, all integrated into the U.S. *Ballistic Missile Defense System* (BMDS) architecture: (1) Satellite-based, early-warning infrared sensors (2) three upgraded early-warning phased-array radars at Beale AFB (Cal.), RAF Fylingdales (UK) and Thule Air Base (Greenland) (3) forward-based X-band AN/TPY-2 radars to determine missile trajectories as well as (4) the *Cobra Dane* radar at Earechson Air Station on the island of Shemya, in the Alaskan Aleutian Islands, and the sea-based

1 For historical BMD funding FY85-17 see: https://www.mda.mil/global/documents/pdf/FY17_histfunds.pdf [09/30/19].

x-band radar (SBX), which is meant for further tracking of missiles and warheads in their midcourse-phase, providing object classification and updated guidance information to the interceptors.[2] Two additional upgraded early-warning radars in Clear, Alaska, and Cape Cod, Massachusetts, respectively, are scheduled to be certified in the near future. Until then, the predecessor radars of the old PAVE PAWS type will remain in operation as part of the early warning system.[3] The development of the *Long Range Discrimination Radar* (LRDR), a midcourse sensor to be deployed in Alaska, is also under way.

The GMD program is the core element of U.S *Homeland Defense* and is designed to protect the United States against long-range ballistic missile attacks. Until now, GMD is the only system designated to deal with ICBM threats. Formerly initiated within the framework of *National Missile Defense* in the late 1990s and renamed under the Bush Administration in 2002, today's GMD program rely on three main key elements; early warning, tracking and target classification and acquisition data provided by the BMDS sensor network, *Ground-Based Interceptors* (GBI), and a *Battle Management Command, Control and Communications* (BMC3) system.

At the moment a total of 44 three-stage GBI interceptors are deployed in the U.S., 40 GBIs stationed in Fort Greely, Alaska and four at the Vandenberg Air Force Base in California. For the moment no more GBI interceptors will be built or fielded, instead a new type of GMD interceptor is planned to be developed within the next years.[4] The GBI interceptors consist of a three-stage solid-fuel booster, carrying a so-called *Exo-atmospheric Kill Vehicle* (EKV) into space which, once released, is directed towards the predicted position of the approaching warhead in its midcourse-flight-phase. During the final hundred kilometers of its journey, the EKV locks onto the target using its onboard sensors, and is intended to collide with the attacking warhead, destroying it by virtue of its kinetic energy (hit-to-kill). Originally, the George W. Bush Administration agreed on a supplemental European component of GMD in order to defeat ICBMs approaching the U.S. from the Middle East. In the framework of this *European Midcourse Defense* (EMD) approach, it was originally planned to install 10 two-stage GBI-interceptors near Redzikowo in Poland between 2011 and 2013, a *European Midcourse Radar* (EMR) in the Czech Republic and an advanced mobile x-band radar in South East Europe or the Middle East. However, the EMD plan was replaced by the Obama-Administration in 2009, referring to a changed threat assessment in favor of a ship-based *Aegis* missile defense system.

Even though the three-stage GBI interceptors are already in service, their testing program still continues. According to the MDA, 19 intercept tests have been carried out between 1999 and 2019, only eleven of them have been rated as successes.[5] The last two successful intercept tests took place on May 30th 2017 and March 25th 2019. As the MDA stated, the 2017 test was the first test against an ICBM-like target and the 2019 test was furthermore the first

2 MDA (2016a): The System – Elements- Sensors, MDA website, https://www.mda.mil/system/sensors.html [09/30/19].

3 Williams, Ian (2018): Upgraded Early Warning Radar (UEWR), Missile Threat, Center for Strategic and International Studies, April 14, 2016, last modified June 15, 2018, https://missilethreat.csis.org/defsys/uewr/. [09/30/19]

4 Judson, Jane (2019): Pentagon terminates program for redesigned kill vehicle, preps for new competition, DefenseNews.com, August 21, 2019, https://www.defensenews.com/pentagon/2019/08/21/dod-tanks-redesigned-kill-vehicle-program-for-homeland-defense-interceptor/ [09/30/19].

5 MDA (2019a): Ballistic Missile Defense Intercept Flight Test Record, Missile Defense Agency, as of September 2019, https://www.mda.mil/global/documents/pdf/testrecord.pdf [08/30/17].

salvo/dual intercept test.[6,7]

Previously, GBI Interceptors had only been tested against target-missiles with ranges less than 5.000 km. Many experts have criticized tests carried out under unrealistic conditions, and deny their meaningfulness to a real-life mission. A *Union of Concerned Scientists* (UCS) study from 2016 concluded that "the Pentagon's own testing officials have stated that the system has not demonstrated an operational capability to defend the U.S. public from a missile attack".[8] U.S. *Government Accountability Office* (GAO) reports have repeatedly criticized a lack of transparency by the MDA, cost overruns and high-risk acquisition practices. In 2016, GAO asserted that MDA had not "demonstrated through flight testing that it can defend the U.S. Homeland against the current missile defense threat".[9] The current testing also does not include sophisticated countermeasures an attacker could use in order to confuse the defense, by e.g. using light decoys, balloons and debris or warhead mockups.

Despite the sobering test results, advocates in the US Congress demand an expansion of the national GMD, pushing to build a "third NMD site" on the East Coast of the USA. In May 2016, the Pentagon completed a draft study of three possible locations on the Eastern US coast for a new BMD interceptor site, but there is still no decision made to actually build such a site, which could run up a bill of US$3-4 billion.[10]

Regional and area missile defense

The US regional BMD programs are supposed to protect US oversea regions, forward based troops and allied territories. The naval Aegis Ballistic Missile Defense system and the land-based *Theater High Altitude Area Defense* (THAAD) are addressing specifically the short- and medium-range ballistic missile threat. The *Patriot* PAC-3 system is capable to defend only close range areas against short-range ballistic missiles.

The Sea-based and Ashore Aegis Missile Defense

The *Aegis Ballistic Missile Defense* system (*Aegis BMD*) of the US Navy is primarily designed to intercept ballistic missiles in their mid-course-phase. However, initial tests have been carried out to also prove the systems capabilities to intercept medium-range missiles in their terminal-phase and long-term plans exist to use *Aegis BMD* to defeat ballistic missiles in their ascent-phase. The primary mission of *Aegis BMD* is of wide-area defense, which could further be enlarged by increasing the number of deployed systems, becoming potentially capable of protecting whole regions. Core elements of *Aegis BMD* are the *Aegis*

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6 Freedberg Jr., Sydney J. (2017): Missile Defense Test 'Realistic,' Syring Insists, Breaking Defense, Mai 31, 2017, http://breakingdefense.com/2017/05/missile-defense-test-realistic-syring-insists/ [08/30/17].

7 Panda, Ankit (2019): Missile Defense Milestone: US Carries Out Successful 'Salvo' Interception of ICBM Target, The Diplomat, March 26 2019, https://thediplomat.com/2019/03/missile-defense-milestone-us-carries-out-successful-salvo-interception-of-icbm-target/ [09/30/19].

8 UCS (2016): Shielded from Oversight: The Disastrous US Approach to Strategic Missile Defense, Union of Concerned Scientistes, p.2, 2016.

9 GAO (2016): Missile Defense: Assessment of DOD's Reports on Status of Efforts and Options for Improving Homeland Missile Defense, U.S. Governmental Accountability Office, GAO-16-254R, p.6, February 2017, Washington D.C., http://www.gao.gov/assets/680/675263.pdf [08/30/17].

10 Reif, Kingston (2016): Pentagon Completes Missile Defense Study, Arms Control Today, July/August 2016, https://www.armscontrol.org/act/2016-07/news-briefs/pentagon-completes-missile-defense-study [09/30/19] & Reif, Kingston (2019): Congress Seeks Decision on Missile Defense Site, Arms Control Today, June 2019, https://www.armscontrol.org/act/2019-06/news-briefs/congress-seeks-decision-missile-defense-site [09/30/19].

Weapon System (AWS),[11] a computer-based command, control and decision interface, the An/SPY-1 radar with a search-, early warning- and tracking capacity, and different models of the *Standard Missile* (SM) interceptor which are assigned for special types of application. Originally developed and first stationed in 1983, in order to conduct air defense missions, the systems first SM models had only very limited capacities to defend areas against short-range ballistic missiles.[12] After updating the AWS and introducing new interceptors over the years, the current *Aegis Combat Systems* are meant to handle both - i.e., air defense tasks and an increasing spectrum of missile threats. *Aegis BMD* therefore represents a further development and upgrade of the original *Aegis*-System, and in particular requiring an advanced interceptor and the modification of the radar and Command & Control (C&C) software. Such an upgrade costs about 45 up to 55 Million US-Dollars per ship.[13] Basically three different models of *Standard Missile* interceptors are used by *Aegis BMD* systems today; SM-2 Block IV, SM-3 Block IA and Block IB interceptors.

The SM-2 Block IV interceptor has a range of up to 370 km and only a limited BMD capability.[14] Its successor, the new "SM-6 Extended Range", is a BMD version of the SM-6 and currently being fielded.[15] Both interceptors are being deployed to intercept *Short-Rrange Ballistic Missiles* (SRBM) within the atmosphere. The new SM-6 has an increased maneuverability and extended range, designed to be capable of intercepting MRBMs in the terminal-phase (sea-based terminal defense) as well as to defeat cruise missiles.[16,17] The SM-2 and SM-6 endo-atmospheric interceptors are equipped with an explosive warhead, detonating in close distance to the target and destroying it by blast fragmentation.

SM-3-Interceptors have been developed to protect larger areas and are meant to intercept ballistic missiles and warheads in the mid-course-flight-phase (*Aegis Midcourse Defense*), using a kinetic kill-vehicle. The target is to be destroyed outside the atmosphere by a directed collision with the kill-vehicle and through the released kinetic energy (hit-to-kill). Today's deployed interceptors are of the type SM-3 Block IA or Block IB and the joint development (with Japan) of an advanced SM-3 Block IIA interceptor is in progress. The further development of interceptors focuses in particular on an extended range, by increasing the flying speed, as well as an enhanced targeting precision, by improving the sensors of the kill-vehicle. The SM-3 Block I interceptor has a range of at least 800 km and is intended to intercept *Short- and Medium-Range Ballistic Missiles* (SRBM/MRBM) in altitudes between 70 and 300 km.[18] The SM-3 Block IB, equipped with an improved kill-vehicle, was successfully tested for the first time in the summer of 2012 and has been

11 For further information see e.g. US Navy (2017a): Aegis Weapon System, United States Navy Fact File, http://www.navy.mil/navydata/fact_display.asp?cid=2100&tid=200&ct=2 [08/30/17].

12 US Navy (2017b): Standard Missile, Fact File, United States Navy, as of January 30, 2017.

13 O'Rourke, Ronald (2012): Navy Aegis Ballistic Missile Defense (BMD) Program: Background and Issues for Congress, CRS Report for Congress, October 25, 2012

14 US Navy (2017b).

15 O'Rourke, Ronald (2019): Navy Aegis Ballistic Missile Defense (BMD) Program: Background and Issues for Congress, CRS Report for Congress, RL33745, June 21, 2019.

16 MDA (2016b): MDA conducts SM-6 MRBM intercept test, MDA NEWS Release, 16-NEWS-0012, December 14, 2016.

17 Freedberg Jr., Sidney (2014): Non-Standard: NavySM-6 Kills Cruise Missiles Deep Inland, Breaking Defense, August 19, 2014, http://www.breakingdefense.com/2014/08/non-standard-navy-sm-6-kills-cruise-missiles-deep-inland [08/30/17].

18 Neuneck, Götz, Christian Alwardt & Hans Christian Gils (2015): Raketenabwehr in Europa, Nomos, Baden-Baden, 2015.

deployed since 2014.[19,20] The SM-3 Block II interceptors differ fundamentally from the currently deployed Block IA/IB versions. They have a diameter of approximately 53 cm (21 inches) over their entire length. The SM-3 Block IIA is equipped with a more efficient sensor and is able to carry more fuel, reaching a 45-60% higher top speed and having an advanced range, and thus is capable of defending larger areas.[21,22] The SM-3 Block IIA is being developed in cooperation with Japan and deployment was originally scheduled for the beginning of 2018.[23] In February 2017 the SM-3 Block IIA interceptor has successfully conducted its first intercept test.[24] On November 16, 2020, the US reported that the SM-3 Block-IIA successfully intercepted an ICBM near the coast of Hawaii in a flight test.[25] The price for a SM-3 Block IB interceptor is stated at US$10-12 million, for a SM-3 Block IIA at US$20-24 million.[26]

With a range of about 310 km, the current AN/SPY-1 radar has only a limited coverage and therefore it primarily serves as a guidance radar for the *Standard Missile* interceptors.[27] However, in a forward deployed position these radars could also contribute additional sensor data for the use of other defense systems, such as the GMD. The latest *Arleigh-Burke* ship design (Flight III), currently under development, will be equipped with the new *Air Missile Defense Radar* (AMDR) and will be referred to as AN/SPY-6. According to the manufacturers, Raytheon, this radar, when compared with the AN/SPY-1, will enable an *Arleigh-Burke* destroyer to detect a target of half the size at twice the distance.[28]

By the end of FY2018, the U.S. maintained 38 Aegis ships (destroyers of the *Arleigh-Burke*-class and *Ticonderoga*-cruisers) having a BMD capability.[29] Some of these ships were able to perform both air and missile defense simultaneously.[30] These "advanced" *Aegis* BMD ships are equipped with an *Aegis* BMD 5.0 or higher system and the newest AWS Baseline 9.X Combat System.[31] These ships will also be able to fire SM-2 IV, SM-3 as well as SM-6 interceptors within the same combat setting in order to defeat attacking ballistic missiles in their midcourse and in their terminal phase (exo- and endo-atmospheric intercepts). The current U.S. minimum

19 Raytheon (2012): Newest SM-3 takes out another ballistic missile target, News Release, June 27, 2012, http://raytheon.mediaroom.com/index.php?item=2117 [08/30/17].
20 Raytheon (2014): US Navy deploys Standard Missile-3 Block IB for first time, News Release, April 23, 2014, http://raytheon.mediaroom.com/index.php?s=43&item=2548 [08/30/17].
21 Postol, Theodore A. (2007): The Proposed US Missile Defense in Europe – Technological Issues Relevant to Policy, Lecture at Carnegie Center Moscow, November 15, 2007.
22 O'Rourke (2019).
23 MDA (2017a): Aegis Ballistic Missile Defense – Status, see website of the Missile Defense Agency: https://www.mda.mil/system/aegis_bmd.html [02/12/21].
24 MDA (2017b): U.S. Japan Successfully Conduct First SM-3 Block IIA Intercept Test, MDA NEWS Release, 17-NEWS-0002, February 3, 2017.
25 DoD (2020): U.S. Successfully Conducts SM-3 Block IIA Intercept Test Against an Intercontinental Ballistic Missile Target, Press Release, US Department of Defense, https://www.defense.gov/Newsroom/Releases/Release/Article/2417334/us-successfully-conducts-sm-3-block-iia-intercept-test-against-an-intercontinen/ [02/12/21].
26 O'Rourke, Ronald (2015): Navy Aegis Ballistic Missile Defense (BMD) Program: Background and Issues for Congress, CRD Report, p.4, November 10, 2015.
27 Lewis, George (2012): Ballistic Missile Defense: The Aegis SPY-1 Radar, Mostly Missile Defense Blog, August 3, 2012, https://mostlymissiledefense.com/2012/08/03/ballistic-missile-defense-the-aegis-spy-1-radar-august-3-2012/ [08/30/17].
28 See infographics at Raytheon Website, http://www.raytheon.com/capabilities/products/amdr/ [08/30/17].
29 O'Rourke (2019).
30 MDA (2017a).
31 Lewis, George N. (2015): How Many Aegis BMD Ships in 2040?, Mostly Missile Defense Blog, December 13, 2015; https://mostlymissiledefense.com/2015/12/13/how-many-aegis-bmd-ships-in-2040-december-13-2015/ [08/30/17].

requirements for Aegis BMD are 54 ships, four stationed in the framework of Barak Obama's *European Phased Adaptive Approach* (EPAA), nine deployed in the periphery of Japan, 30 ships for the U.S. carrier battle groups and 11 for independent BMD deployment demands. Due to the U.S. Navy, these requirements will not be met before 2024.[32] Nevertheless, by the end of 2017 at least three 'advanced' *Aegis* ships were deployed in Japan. Each destroyer of the *Arleigh-Burke*-class can be equipped with up to 122 SM-3 interceptors, while the *Ticonderoga*-cruisers can carry up to 96.[33]

With the deployment of the SM-3 IIA interceptor the capabilities of these 'advanced' *Aegis* BMD ships will further increase, both in missile defense coverage as well as in kill-probability. In regard to the further U.S. acquisition and deployment of SM-3 IIA interceptors, estimations of the future inventory vary between around 220 to 415 interceptors in 2030 and 275 to 610 interceptors in the mid-2030s.[34] Many experts believe the SM-3 IIA to have the necessary performance to intercept an ICBM in its descending phase, provided that the interceptor is stationed at an appropriate geographic location within reach of the terminal segment of the ICBM's trajectory.[35,36] Therefore, *Aegis* ships with SM-3 IIA interceptors and located near the U.S. West or East Coast could one day serve as a second U.S. Homeland defense layer. In addition, there seem to be plans to further develop the SM-3 IIA interceptor, enabling it to intercept attacking missiles in their ascent-phase.[37]

In the framework of the EPPA, four Aegis BMD ships are permanently deployed to the Mediterranean Sea and a forward-based FBX radar is stationed in Turkey. In Romania a land-based *Aegis Ashore* site, adapting the ship-based *Aegis* system to land locations became operational in 2016, along with 24 SM-3 Block IB interceptors and an AN/SPY-1 radar. A second *Aegis Ashore* site in Poland is under construction and might be put into service in FY2020.[38] Since the Aegis Ashore SM-3 launch system is based on ship-based Mk 41 Vertical Launching Systems (VLS) that are also capable of launching

nuclear tipped cruise missiles, Russia is concerned that interceptors at Aegis Ashore sites could readily be replaced by offensive strike weapons. Therefore, Russia sees the EPAA as an emerging military threat, endangering the strategic stability.

As the MDA states, the *Aegis* BMD system has been able to carry out 40 successful intercepts in 49 attempts against ballistic missile targets since 2002.[39] In addition, a decommissioned U.S. satellite was shot down successfully by a SM-3 interceptor in February 2008,[40] demonstrating their possible use an anti-satellite weapon. In general, experts have often criticized *Aegis* BMD tests as, like GMD tests, they are neither carried out under real-life conditions nor do they include any countermeasures and they are therefore

32 O'Rourke (2019).
33 Gates, Robert & James Cartwright (2009): DoD News Briefing, September 17, 2009, http://www.defenselink.mil/transcripts/transcript.aspx?transcriptid=4479 [09/26/15].
34 Lewis, George N. (2016a): How Many SM-3 Block IIA Missiles, Mostly Missile Defense Blog, January 25, 2016; https://mostlymissiledefense.com/2016/01/25/how-many-sm-3-block-iia-missiles-january-25-2016/#more-1111 [08/30/17].
35 Lewis, George N. (2016b): Strategic Capabilities of SM-3 Block IIA Interceptors, Mostly Missile Defense Blog, June 30, 2016; https://mostlymissiledefense.com/2016/06/30/strategic-capabilities-of-sm-3-block-iia-interceptors-june-30-2016/ [08/30/17].
36 Lewis (2016a).
37 MDA (2008): AEGIS Ballistic Missile Defense: Status, Integration and Interoperability, slide 5, May 6, 2008; https://mostlymissiledefense.files.wordpress.com/2013/09/2008-5-aegisbmd-statusintergrationandinteroperability.pdf [08/30/17].
38 O'Rourk (2019).
39 MDA (2019a).
40 Kaufman, Marc and Josh White (2008): Navy Missile Hits Satellite, Pentagon Says, Washington Post, February 21, 2008.

not conclusive.[41,42]

The Terminal High Altitude Area Defense

The *Terminal High Altitude Area Defense* (THAAD) is a mobile, land-based missile defense system operated by the U.S. Army. THAAD is designed to intercept incoming threats, such as SRBMs and MRBMs at the end of the midcourse-phase and within the terminal-phase. Approaching targets are destroyed, using hit-to-kill technology and intercepts can take place both, inside or almost outside the earth's atmosphere.[43] THAAD is deployed primarily to protect small regions or areas, such as population centers or military bases.

A THAAD battery consist of the following elements: a truck-based launch platform for eight THAAD interceptors; an AN/TPY-2-radar for tracking, target discrimination and fire-control support; and a mobile, tactical command-control-center for data and communication processing and up-linking the system to external missile defense infrastructure. The whole system is globally-transportable by land, sea and air.[44] According to the MDA, the THAAD interceptors are capable of intercepting medium-range ballistic missiles with ranges of up to 3000 km.[45] The price for a THAAD battery is about US$800 million.[46]

The range of the AN/TPY-2 radar depends on its operation mode (terminal or forward-based mode) and on the nature of the target. Considering different operation-scenarios, experts estimate the radar to have a case-related range somewhere in between 600 km and 3,000 km.[47]

The MDA states that since 2006 THAAD has been tested 18 times, including 16 'successful' intercepts (including two salvo/dual intercept tests). Four interception attempts were classified as 'non-tests' (target malfunctioned after launch and/or interceptors were not launched).[48] In October 2012, the MDA succeeded for the first time in shooting a medium range rocket.[49] The MDA has also stated[50] that the first test against an IRBM was conducted in the beginning of July 2017. However, doubts persist as to whether testing conditions match the real-life requirements.

Seven THAAD batteries have been delivered to the U.S. Army so far.[51] One of these THAAD batteries was stationed at Guam in 2013 to protect the island against potential North Korean missile attack. In July 2016, the U.S. and South Korea agreed on deploying anoth-

41 Wright, David; Gronlund, Lisbeth (2009): Technical Flaws in the Obama Missile Defense Plan, Bulletin of the Atomic Scientist, September 23, 2009.

42 Lewis, George N. and Theodore A. Postol (2010): A Flawed and Dangerous U.S. Missile Defense Plan, Arms Control Today, May 2010.

43 MDA (2017c): *Terminal High Altitude Area Defense, Fact Sheet*, as of June 2017, https://www.mda.mil/global/documents/pdf/thaad.pdf [08/30/17].

44 MDA (2017c).

45 MDA (2007): Programmatic Environmental Impact Statement, January 2007, Vol. 2, p.D-36, https://www.mda.mil/global/documents/pdf/env_bmds_peis_vol2.pdf [08/30/17].

46 Barnes, Julian E and Entous, Adam (2013): With an Eye on Pyongyang, U.S. Sending Missile Defenses to Guam. The Wall Street Journal, April 4, 2013, https://www.wsj.com/articles/SB10001424127887323916304578400700347158398 [02/12/21].

47 Lewis, George N. (2016c): THAAD Radar Ranges, Mostly Missile Defense Blog, June 30, 2016; https://mostlymissiledefense.com/2016/07/17/thaad-radar-ranges-july-17-2018 [08/30/17].

48 MDA (2019a).

49 MDA (2012): Ballistic Missile Defense System Engages Five Targets Simultaneously During Largest Missile Defense Flight Test in History, October 25, 2012, https://www.mda.mil/news/12news0011.html [08/30/17].

50 MDA (2017d): THAAD Successfully Intercepts Target in Missile Defense Test, July 11, 2017, https://www.mda.mil/news/17news0007.html [08/30/17].

51 MDA (2019b): : Fiscal Year (FY) 2020 Budget Estimates, Overview, Missile Defense Agency, 19-MDA-9955, March 7, 2019, https://www.mda.mil/global/documents/pdf/budgetfy20.pdf [09/30/19].

er THAAD battery in South Korea in order to protect parts of the southern Korean Peninsula against the North Korean threat.[52] This decision caused much controversy in South Korea, nevertheless deployment has started at the beginning of 2017.[53] Meanwhile the system has reached operational status. China has articulated strong objections concerning this THAAD deployment and especially against the THAAD radar. Operating in the special 'forward-based' mode (FBX), it might be able to monitor Chinese ICBM launches. Therefore, the decision to station such a system in its neighborhood is seriously annoying China. China's foreign ministry spokeswoman Hua Chunying stated that "the U.S. deployment of THAAD on the Korean Peninsula seriously damages the strategic balance in the region and seriously harms the strategic security interests of relevant regional countries, including China".[54]

52 Reuters (2016): U.S. to deploy THAAD anti-missile battery in South Korea in 8-10 months: commander, Reuters.com, November 4, 2016, http://www.reuters.com/article/us-southkorea-usa-thaad/u-s-to-deploy-thaad-anti-missile-battery-in-south-korea-in-8-10-months-commander-idUSKBN12Z028 [08/30/17].

53 Johnson, Alex, Courtney Kube & Stella Kim (2017): U.S. Begins Shipping Controversial Anti-Missile System to South Korea, NBCNEWS, March 7, 2017.

54 Reuters (2016).

Patriot Air and Missile Defense System

With the *Patriot* system, the United States have developed one of the most used and operated tactical air and missile defense systems. It has been exported to various foreign countries and is a point-defense system with only a small interception-radius, intended to defend military bases, critical infrastructures or small areas. It is based on highly mobile truck-mounted components and in its latest configuration, a *Patriot* battery consists of an AN/MPQ-65 radar, launch stations of the type M903, an *Engagement Control Station* (ECS), as well as several supporting systems for power generation and communications. Depending on the type of interceptor, each launch station can be loaded with up to 16 different interceptors of the MIM-104 series.[55]

Entering service almost 40 years ago, the *Patriot* system was originally developed as an air defense system. The first and second generation, the *Patriot Advanced Capability* 1 and 2 (PAC-1 & PAC-2) utilized interceptors with a high-explosive warhead intended to engage and destroy the target through fragmentation effects produced by its explosion in close proximity. The third Generation PAC-3, available since 2001, aims to destroy the target via direct kinetic energy released from the physical collision with a hit-to-kill vehicle. In principle, these PAC-3 interceptors offer an extended effectiveness in the defense against short-range ballistic missiles. Overtime, 14 different production versions of MIM-104 series interceptors have been developed for the *Patriot* system. The most recent interceptors are the PAC-2 *Guidance Enhanced Missile - Tactical* ballistic missile (GEM-T) and the PAC-3 *Missile Segment Enhancement* (MSE).[56] Whereas the PAC-2 GEM-T can engage aircrafts and other air-breathing threats such as cruise missiles, as well as some types of tactical ballistic missiles, the primary mission of PAC-3 MSE is to engage short-range ballistic missiles in the terminal-phase of their flight. The *Patriot* ground-radar system is responsible for all search, acquisition, targeting, and guidance tasks. When intercepting a ballistic missile, the PAC-3 interceptor only takes over control shortly before engaging the target using active target tracking, which is achieved by an active Ka-band radar enabling the interceptor to calculate necessary onboard maneuvers and to correct the flight path in order to hit the target in its terminal flight-phase. Currently, a follow-up for the

55 Hawkes, John (2019): Patriot games: Raytheon's air-defence system continues to proliferate, Jane's International Defence Review, Vol 52, January 2019, ihs.com/janes.

56 Hawkes 2019.

Patriot radar is under development, known as the *Active Electronically Scanned Array* (AESA) Gallium-Nitride (GaN) radar.[57] The AESA GaN radar adds 360-degree radar coverage and is meant to be more powerful, more efficient and cheaper in operation. The latest *Patriot* system software update also makes it compatible with the new *Integrated Battle Command System* (IBCS) of the US Army.[58]

The *Patriot* system is not only the most widely operated missile defense system of its type, but it is also considered to be highly proven, as it has been defeating ballistic missiles since its first use during US operations *Desert Shield* and *Desert Storm* in 1991. However, many experts challenge this narrative based on poor interception results during the two *Gulf Wars* in 1991 and 2003, respectively.[59] US officials state that results have improved during the years showing a 'proven combat record' during *Operation Iraqi Freedom* in 2003.[60] The US is currently operating 60 *Patriot* batteries[61] and has fielded *Patriot* systems in many different countries, including South Korea, Poland and Iraq. Since 2013, *Patriot* systems have also been deployed in Turkey by an international coalition of NATO states as a response to a perceived ballistic missile threat from the Syrian Regime. Recently, *Patriot* systems have been used by Saudi Arabia and the UAE in the Yemen conflict.

With the signing of contracts in 2018 with Poland, Sweden, and Romania, the *Patriot* user community has grown to 17 countries.[62] In the meantime, many of these countries have shown an interest in upgrading their systems to the latest and the most capable PAC-3 MSE interceptor version. Furthermore, in November 2018, the US government agreed on a PAC-3 MSE sale to Germany for integration with its future TLVS air and missile defense system.[63]

According to Raytheon, the *Patriot* contractor, the system, has so far been used in "more than 250 combat engagements against manned and unmanned aircraft, cruise missiles, and tactical ballistic missiles." Furthermore, since January 2015, "Patriot has intercepted more than 150 ballistic missiles in combat operations around the world".[64] In contrast, experts still have doubts concerning the combat records and the interception-successes of Patriot systems, with a recent example being Saudi Arabia.[65] The claims by the US Government that the Patriot is a 'proven system' is not backed up by independent testing information available to the public.

57 McDougall, Shaun (2019): Raytheon Wins U.S. Army Patriot Radar Replacement Competition, Defense & Security Monitor, October 17, 2019, https://dsm.forecastinternational.com/wordpress/2019/10/17/raytheon-wins-u-s-army-patriot-radar-replacement-competition/ [04/14/20].

58 Hawkes 2019.

59 Korda, Matt & Kristensen, Hans M. (2019): US ballistic missile defenses, 2019, Bulletin of the Atomic Scientists, 75:6, 295-306, https://doi.org/10.1080/00963402.2019.1680055 [04/14/20].

60 DoD (2019): Missile Defense Review 2019, US Department of Defense, https://media.defense.gov/2019/Jan/17/2002080666/-1/-1/1/2019-MISSILE-DEFENSE-REVIEW.PDF [04/14/20].

61 DoD (2019).

62 As of April 2020 these countries are; Egypt, Germany, Greece, Israel, Japan, Jordan, Kuwait, the Netherlands, Poland, Qatar, Romania, Saudi Arabia, Spain, Sweden, UAE, USA and Taiwan.

63 Hawkes 2019.

64 Raytheon (2020): Global Patriot Solutions, Raytheon website: https://www.raytheonmissilesanddefense.com/capabilities/products/global-patriot-solutions [data as of April 9, 2020].

65 Lewis, Jeffrey (2018): Patriot Missiles Are Made in America and Fail Everywhere, Foreign Policy, March 28, 2018, https://foreignpolicy.com/2018/03/28/patriot-missiles-are-made-in-america-and-fail-everywhere/ [04/14/20].

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