Director, Operational Test and Evaluation

2015 Assessment of the Ballistic Missile Defense System (BMDS)

April 2016

This report satisfies the provisions of the National Defense Authorization Act for Fiscal Year 2002, Section 232 (h), as amended by subsequent Acts, which mandates that the Director, Operational Test and Evaluation annually characterize the operational effectiveness, suitability, and survivability of the BMDS, and its elements, that have been fielded or tested before the end of the preceding fiscal year. The Act also requires the Director to assess the adequacy and sufficiency of the BMDS test program during the preceding fiscal year. This report is unclassified. Supplemental information is contained in classified version of this report.

J. Michael Gilmore
Director

This page intentionally left blank.

Executive Summary

This report supports the congressional reporting requirements of the Director, Operational Test and Evaluation (DOT&E) as they pertain to the Ballistic Missile Defense System (BMDS). Congress specified these requirements in the fiscal year 2002 (FY02) National Defense Authorization Act (NDAA). The FY09 NDAA, Section 234, amends the FY02 NDAA to consolidate the reporting requirements of both the FY02 and the FY06 NDAAs.

The FY02 NDAA, as amended, mandates that DOT&E each year characterize the operational effectiveness, suitability, and survivability of the BMDS and its elements that the Missile Defense Agency (MDA) has fielded or tested prior to the end of the preceding fiscal year. The act also requires DOT&E to assess the adequacy and sufficiency of the BMDS test program during the preceding fiscal year.

This report assesses the performance and test adequacy of the BMDS, its four autonomous BMDS systems, and its sensor/command and control architecture. The four autonomous BMDS systems are the Ground-based Midcourse Defense (GMD), Aegis Ballistic Missile Defense (Aegis BMD), Terminal High-Altitude Area Defense (THAAD), and Patriot. The Command and Control, Battle Management, and Communications (C2BMC) element anchors the sensor/command and control architecture. This report covers the period from October 1, 2014 through December 31, 2015. Many of the details of the performance of the BMDS are classified, and are included in the classified version of this report.

The MDA conducted 13 flight test events and 4 ground tests during FY/calendar year 2015 (CY15), in accordance with the DOT&E-approved Integrated Master Test Plan (IMTP).[1]

As with previous DOT&E BMDS assessment reports, some of the assessments in this report are limited by the amount of available test data and the resulting limited verification, validation, and accreditation (VV&A) of the required BMDS modeling and simulation (M&S). As the MDA continues to execute the IMTP, additional test data supporting quantitative assessments will become available. As data are collected, DOT&E's BMDS assessments will incrementally become more quantitative. Although more Aegis BMD, THAAD, and Patriot M&S are successfully completing VV&A, it is unknown when sufficient test data will be available to adequately verify, validate, and accredit the GMD M&S to allow quantitative performance assessments for GMD.

Operational Effectiveness, Suitability, and Survivability

The operational effectiveness of the BMDS refers to its ability to defend the United States, deployed forces, and allies against ballistic missiles of all ranges (short-range, medium-range, intermediate-range, and intercontinental ballistic missiles; or SRBMs, MRBMs, IRBMs,

[1] IMTP version 15.1 dated May 11, 2015.

and ICBMs).[2] This report assesses the operational effectiveness of the BMDS and each of the autonomous BMDS systems (i.e., GMD, Aegis BMD, THAAD, and Patriot) that comprise it for defended areas within U.S. Northern Command (USNORTHCOM), U.S. European Command (USEUCOM), U.S. Central Command (USCENTCOM), and U.S. Pacific Command (USPACOM). The overall body of knowledge at the BMDS level is still insufficient to permit quantitative assessments of operational effectiveness. Hence, the BMDS-level assessments in this report are qualitative. The body of knowledge for the autonomous BMDS systems, however, is sufficient to permit a quantitative assessment of operational effectiveness in many cases. Quantitative operational effectiveness assessments are included in the classified version of this report.

The operational suitability of the BMDS refers to the degree to which the BMDS can be successfully fielded and sustained. The survivability of the BMDS refers to the capability of the system and crew to avoid or withstand a man-made hostile environment. Unlike operational effectiveness, the assessments of BMDS operational suitability and survivability are not broken down by defended areas with each Combatant Command (CCMD) because operational suitability and survivability do not vary significantly for different defended areas. Again, these assessments are classified and are contained in the classified portion of the BMDS report.

<u>Ballistic Missile Defense System (BMDS)</u>. The MDA and Services completed two flight tests and four ground tests in FY/CY15 that collected data on overall BMDS effectiveness. Flight Test Operational-02 (FTO-02) Event 1a (December 2015) provided a demonstration of the Aegis Ashore Missile Defense System (AAMDS) capability to defend Europe as part of the European Phased Adaptive Approach (EPAA).[3] FTO-02 Event 2a (November 2015) was a test of a USEUCOM scenario using Aegis BMD and THAAD against SRBM and MRBM targets, while Aegis BMD simultaneously conducted Anti-Air Warfare operations against a cruise missile surrogate.

<u>Ground-based Midcourse Defense (GMD)</u>. GMD has demonstrated capability against small numbers of simple ballistic missile threats launched from North Korea and Iran, but a quantitative assessment is currently not possible. A quantitative assessment will require extensive ground testing that is supported by M&S accredited for performance assessment and grounded in flight testing. Such accreditation has not been completed.

The reliability and availability of the operational Ground-Based Interceptors (GBIs) are low, and the MDA continues to discover new failure modes during testing. Several Exo-atmospheric Kill Vehicle (EKV) fixes were demonstrated in the most recent intercept flight

---

[2] According to the MDA and the intelligence community: SRBM – less than 1,000 kilometers; MRBM – 1,000 to 3,000 kilometers; IRBM – 3,000 to 5,500 kilometers; ICBM – greater than 5,500 kilometers

[3] The AAMDS comprises the Aegis Weapon System (AWS) Baseline 9 (BL9) hardware and software adapted for deployment on land. The BMD capabilities in AWS BL9 improve upon those of the Aegis BMD 4.0 system, including improvements in IAMD capabilities for Aegis BL9.C1 destroyers. The first deployed AAMDS site is located in Deveselu, Romania, with a second site to be deployed in Poland in 2018.

test (Flight Test GBI-06b (FTG-06b); FY14). The Capability Enhancement-I (CE-I) EKV experienced a flight test failure during FTG-07 in FY13. While the GBI was in flight, a voltage shift caused by battery electrolyte leakage shut down the flight computer and prevented EKV separation. The MDA developed and fully tested EKV software for CE-I GBIs, which included a capability to reset and recover the flight computer following a voltage shift. This software is now fielded to all deployed CE-I EKVs. The MDA is developing new battery and ground ties, and once tested, plans to incorporate them into the CE-II Block 1 deliveries beginning in FY16. The MDA conducted a non-intercept test of the CE-II Block 1 GBI, denoted as Ground-based Midcourse Controlled Test Vehicle 02+ (GM CTV-02+), in January 2016. Results from that test will provide data to inform the MDA's decision to proceed with the CE-II Block 1 builds and deliveries. As of the date of this report, the MDA was still analyzing the data from that test.

GMD survivability data are limited, and come primarily from facility testing and component-level testing.

Aegis BMD. Three Aegis BMD variants are currently available, or are soon to be available, for fielding: Aegis BMD 3.6.3, Aegis BMD 4.0, and Aegis Weapon System (AWS) Baseline 9.1 (BL9.1). The discussion here focuses on the effectiveness, suitability, and survivability of the latter two variants.[4]

Aegis BMD 4.0: Flight testing of the Aegis BMD 4.0 system with Standard Missile-3 (SM-3) Block IB guided missiles has demonstrated that the Aegis BMD 4.0 system possesses a capability to engage non-separating and complex-separating SRBM threats, simple-separating MRBM, and lower-range threshold IRBM threats in the midcourse phase of flight using SM-3 Block IB guided missiles.[5] Flight testing in FY15 included a demonstration of the Aegis BMD 4.0 Distributed Weighted Engagement Scheme (DWES), an automated engagement coordination capability, during the Flight Test Other-19 (FTX-19) mission (February 2015). In that mission, two Aegis BMD 4.0 ships demonstrated that the DWES capability can determine the preferred shooter for a given ballistic missile engagement when two Aegis BMD firing assets are present, thereby reducing missile wastage while ensuring BMD threat coverage. DWES is also present in AWS BL9.1. Results from M&S further demonstrated single ship engagement capabilities for a range of real-world scenarios. However, flight testing and M&S did not test the full range of

---

4 The capabilities of Aegis BMD 3.6.3 are very similar to those of the Aegis BMD 3.6.1 build, which was evaluated in DOT&E's FY/CY13 Assessment of the Ballistic Missile Defense System. The At-Sea Demonstration-15 (ASD-15) fleet exercise in October 2015 demonstrated retention of organic midcourse defense capability against non-separating SRBMs.

5 There are two basic threat ballistic missile types. One type is non-separating, in which the warhead payload (or re-entry vehicle (RV)) and the rocket body remain attached throughout the entire missile flight. The second type is separating, in which the RV separates from the missile body. Some separating missile threats employ a post-boost vehicle that separates from the rocket body and then reorients to fine-tune the RV trajectory before ejecting the RV. These missiles are referred to as complex-separating threats. If no post-boost vehicle is employed, then the missile is referred to as a simple-separating threat. SRBMs and MRBMs can be non-separating, simple-separating, or complex-separating missiles. All IRBMs and ICBMs are either simple- or complex-separating missiles.

expected threat types, threat ground ranges, engagement geometries, and threat raid sizes. The 4.0 system ability to engage longer-range MRBM threats is less certain than for lower-range threshold MRBMs because the MDA has only attempted one intercept mission with a ship configured with remote engagements authorized and a forward-based sensor to provide data to the ship, and that flight test involved a non-separating lower-range threshold MRBM.[6] Also, the MDA did not conduct any intercept missions against upper-range threshold MRBMs, i.e., 1,500 to 3,000 kilometers in ground range. Data from flight testing against longer range targets with the AWS BL9.1 system is applicable to the 4.0 system, given their similar engagement capabilities. AWS BL9.1 performance is discussed below.

Analysis of data obtained during flight testing and a maintenance demonstration showed that the Aegis BMD 4.0 system is suitable. Aegis BMD 4.0 meets its threshold requirement for system availability, despite lower than desired command, control, communications, computers, and intelligence hardware reliability and undesirable BMD Signal Processor stability in early flight tests. SM-3 missile failures encountered during flight testing of the Aegis BMD 4.0 system that relate to the third-stage rocket motor (TSRM) have lowered the predicted reliability of the SM-3.[7] An MDA failure review board determined that a re-design of the TSRM nozzle could improve missile reliability. Additional concerns about SM-3 reliability have been raised by flight test observations. Flight Test Standard Missile-25 (FTM-25) (November 2014) and recent lot acceptance testing have shown that the TSRM Attitude Control System cold gas regulator (CGR), which the MDA re-designed following FTM-15 (April 2011), can produce anomalous, low-regulated pressure levels. The MDA established a failure review board to determine the root cause of the low pressure outputs from the CGRs and the investigation is ongoing. The SM-3 Block IB fired in FTO-02 Event 2a (November 2015) had an anomalous G-switch, which prevented the separation of the second stage of the SM-3 from the first.[8]

At the conclusion of FTM-19 in FY13, the MDA conducted a four-part exercise with Aegis BMD 4.0, which demonstrated a capability to perform simultaneous Anti-Air Warfare ship self-defense and BMD functionality. Testing of Aegis BMD 4.0 to date has occurred during available weather conditions, which in most cases, did not reach stressing levels of rain, sea state, or other environmental conditions. The MDA has not conducted tests to determine the effects of nuclear, biological, and chemical environments.

---

6 In an Aegis BMD 4.0 or AWS BL9.1 remote engagement, three different engagement types are possible: (1) a cued engagement, in which the firing asset uses the remote data to search for and detect the threat, completing the engagement as it would an organic engagement; (2) a launch-on-remote-local engagement (LOR-L), in which the firing asset fires an SM-3 variant based on the remote radar data before the local AN/SPY-1 radar has detected and tracked the threat, and then transitions to the local radar data to complete the engagement; and (3) a launch-on-remote-remote engagement (LOR-R), in which remote data are used throughout the engagement. The decision on which of these three modes the system will use is determined based on quality of service metrics implemented in the AWS software.

7 The TSRM is common to both the SM-3 Block IA and SM-3 Block IB missiles.

8 The G-Switch, which is a component of the SM-3 guidance section, is common to all SM-3 variants.

AWS BL9.1: Flight testing of AWS BL9.1, which began in FY/CY15, has demonstrated that AWS BL9.1 possesses a capability to engage simple-separating SRBMs, MRBMs, and lower-range threshold IRBMs in the midcourse phase of flight using SM-3 Block IB guided missiles.[9] Midcourse engagements were made both organically (using the system's own AN/SPY-1 radar) and with the firing asset set up to conduct remote engagements using data provided by a forward-based sensor. The upper range threshold MRBM engaged in FTO-02 Event 1a (by the AAMDS with an SM-3 Block IB Threat Update missile) demonstrated the BL9.1 system capability to engage longer range threats.[10] Additionally, testing demonstrated that AWS BL9.1 destroyers have a capability to engage non-separating SRBMs in the terminal phase of flight with SM-2 Block IV and SM-6 guided missiles. High fidelity M&S analyses using accredited models have not yet been conducted to support a quantitative evaluation of AWS BL9.B1 or AWS BL9.C1 operational effectiveness for midcourse or terminal defense scenarios.

Suitability data obtained during flight testing and a maintenance demonstration for AWS BL9.B1 suggest that it has a lower than desired operational availability. Large repair and logistics delay times contribute to the diminished system availability. Additionally, the software stability of the AWS BL9.1 is lower than desired, although that instability did not translate into a greater number of critical mission failures during flight testing. As noted in the discussion above for the Aegis BMD 4.0 system, SM-3 Block IB missile reliability estimates have been lowered by recent test failures.

Survivability testing of AWS BL9.1 has been limited. FTM-25 and FTO-02 Event 2a demonstrated a degree of AWS BL9.C1 survivability to anti-ship cruise missile attack while simultaneously conducting BMD operations. FTM-25 demonstrated the use of Integrated Air and Missile Defense (IAMD) radar priority mode in a live engagement during which Aegis BMD simultaneously engaged two subsonic cruise missiles and a ballistic missile target. FTO-02 Event 2a included a simultaneous engagement of a cruise missile surrogate and an MRBM target. The Commander, Operational Test and Evaluation Force (COTF) conducted a cybersecurity assessment of AAMDS in August 2015. COTF postponed further cybersecurity testing because of incomplete construction and system integration at the AAMDS site. The cybersecurity testing results are included in the classified portion of the BMDS report.

---

[9] AWS BL9.1 builds include AWS BL9.B1 (AAMDS) and AWS BL9.C1 (version on the Aegis *Arleigh Burke*-class destroyers).

[10] The Threat Update to the SM-3 Block IB guided missile is a software-only update which improves performance against select threat types.

Terminal High-Altitude Area Defense. THAAD has demonstrated operational effectiveness against many SRBM and MRBM targets. In 10 flight tests conducted between FY07 and FY15, THAAD intercepted all 12 target ballistic missiles (5 non-separating SRBMs, 3 simple-separating SRBMs, 1 complex-separating SRBM, and 3 MRBMs).[11,12] One flight test in FY09 demonstrated a salvo engagement and two flight tests in FY12 and FY16 demonstrated dual simultaneous engagements. A full assessment of THAAD effectiveness requires flight tests against more complex targets, and exploration of other parts of the battlespace relevant to longer/faster threats including IRBM targets, and additional M&S with accredited models.

THAAD demonstrated reliability improvements this year during a Reliability Growth Test, but the launchers, particularly the launcher generators, require further improvement to reduce their failure rate. Observations from FTO-02 Event 2 and Event 2a indicate that THAAD Configuration 2 (THAAD 2.0) hardware and software obsolescence changes may have altered the system in unintended ways, so further ground testing is needed. Training is currently insufficient to equip the Soldiers with the knowledge they need to sustain and operate the system when other BMDS elements are in theater, and not all training courses are well-designed. Technical manuals are immature, requiring significant revisions following testing. The THAAD program continues to make progress in resolving the 39 conditions that the Army designated as necessary for the system to improve following the Conditional Materiel Release decision, although the MDA does not plan to complete the remaining 17 conditions until at least FY18. The MDA subjected THAAD to natural environments testing, which included temperature extremes, temperature shock, humidity, rain, ice, snow, sand, dust, and wind. The MDA found deficiencies in all environments, except for wind.

A full assessment of THAAD survivability is contained in the classified portion of the BMDS report. Additional electromagnetic countermeasure testing and cybersecurity testing is needed.

Patriot. The Army first deployed Patriot in 1984. During Operation Iraqi Freedom in 2003, Patriot intercepted all nine Iraqi SRBMs launched against it; however, it also shot down two friendly aircraft due to a combination of training and system shortfalls. Patriot has implemented enhancements and corrective actions to reduce the likelihood of future fratricide incidents. The Patriot configuration assessed in this report uses Post-Deployment Build (PDB-7) system software. This assessment relies upon data collected during the PDB-7 Limited User Test, conducted between May 2012 and January 2013 at White Sands Missile Range, New Mexico.

Patriot met the system effectiveness requirements in the Patriot Capability Development Document against some tactical ballistic missiles; however, it failed to meet requirements against

---

[11] THAAD 1.0 is used to denote the initial hardware and software configuration of THAAD. THAAD 2.0 denotes THAAD Configuration 2 hardware and related software builds.

[12] Most flight testing has been performed using THAAD 1.0; THAAD 2.0 was used in flight tests against the complex separating SRBM target and two MRBM targets.

others. The Patriot PDB-7 system is not suitable. The Mean Time to Repair was 2.5 times the maximum specification threshold value and the Mean Time Between Critical Mission Failure was half the minimum specification threshold value. The Army plans to field the Patriot Radar Digital Processor (RDP) upgrade with PDB-8 in FY18. The RDP is expected to provide enhanced reliability and reduced maintenance overhead for the Patriot radar. Patriot training is not adequate to provide Soldiers with the expertise needed to operate the PDB-7 system with maximum effectiveness. An assessment of Patriot survivability is contained in the classified version of this report.

Command and Control, Battle Management, and Communications (C2BMC). Effective battle management is crucial for the success of the integrated BMDS, and C2BMC is the primary element intended to enable battle management. Spiral 6.4 (S6.4), comprised of the Combatant Command (COCOM) and Global Engagement Manager (GEM) suites, is the currently deployed version of C2BMC. C2BMC S6.4 has demonstrated the capability to provide situational awareness for the BMDS and to forward track data between the BMDS elements. With the addition of the GEM suite, C2BMC S6.4 added the capability to manage multiple AN/TPY-2 (Forward-Based Mode (FBM)) radars.[13] In FY15, C2BMC demonstrated command and control of a single AN/TPY-2 (FBM) radar and Link 16 track reporting during both FTO-02 events. Dual radar management by GEM was demonstrated during distributed ground testing in USEUCOM in support of EPAA Phase 2, and distributed ground testing in USPACOM in support of the second AN/TPY-2 (FBM) radar fielding to Japan in 2014. Flight testing with C2BMC control of two AN/TPY-2 (FBM) radars has yet to occur. However, C2BMC did exercise dual radar management, precision cueing, and system track formation during real-world targets of opportunity in both the USPACOM and USEUCOM areas of responsibility. The MDA also demonstrated C2BMC in cross-CCMD and North Atlantic Treaty Organization exercises in FY15. C2BMC has not demonstrated real-time engagement direction capabilities. The MDA plans to add this capability in future software builds.

BMDS Test Program Adequacy

The assessment of BMDS test program adequacy focuses on three critical attributes: scope, operational realism, and demonstrated testing. Scope comprises the degree of critical data collected, breadth of battlespace tested, extent of threat set covered, and span of BMDS capabilities demonstrated in flight testing. With respect to scope, except for the degree of critical data collected, DOT&E’s assessment is provided in the classified version of this report.

Scope of Testing

At the BMDS level, system flight tests (FTO-02 Event 1a and FTO-02 Event 2a) in FY/CY15 added to the overall body of knowledge for assessing BMDS capabilities. In general, BMDS-level flight testing is still in the early stages and has not yet included integrated Patriot

[13] The GEM suite also provides improved track processing capabilities, but is limited to regional situational awareness only.

participation with overlapping defended areas. Because of the limited number of BMDS-level flight tests, ground tests that use accredited M&S are needed to assess BMDS performance across the entire battlespace. Unfortunately, fully accredited M&S for the BMDS does not currently exist. Operationally realistic communications and network environments during BMDS-level test events are also crucial in determining system-level performance. The MDA has demonstrated the ability to incorporate realistic message traffic in some of the BMDS test events. For the autonomous BMDS systems, flight and ground tests in FY/CY15 expanded the number of threat types, but did not greatly expand the demonstrated battlespace coverage (e.g., intercept altitude versus ground range).

Ground-based Midcourse Defense (GMD). The MDA did not conduct any GMD intercept flight tests in FY/CY15. Since January 2010, GMD intercept flight testing has not supported progress toward accreditation of GBI M&S because of delays and re-tests resulting from GBI flight test failures. Quantitative evaluation of GMD performance will require extensive ground testing with accredited M&S. Data needed to accredit GMD threat, radar, and environmental M&S are either limited or lacking. GMD intercept flight tests have not adequately spanned the operational battlespace to provide data for validation, and subsequent accreditation, of key M&S. The MDA conducted a developmental interceptor flight test (GM CTV-02+) in January 2016 and has plans to conduct one more developmental interceptor flight test and nine intercept flight tests through FY/CY25. The intercept tests include an ICBM engagement test, a salvo engagement test, a test engaging multiple simultaneous threats, and Redesigned Kill Vehicle engagement testing. These tests will support the accreditation of the GBI M&S.

Aegis BMD 4.0 and AWS BL9. Flight and ground testing of Aegis BMD 4.0 has been sufficient to demonstrate performance and allow for an accreditation of M&S tools for organic engagements against SRBMs and lower-range threshold (out to about 1,700 kilometers in ground range) MRBMs. Flight testing of the Aegis BMD remote engagement capability, especially when using external radar data throughout the engagement, is limited, which prevents a quantitative evaluation of remote engagement capabilities. Flight and ground testing in FY/CY15 included demonstrations of the Aegis BMD 4.0 DWES capability. The MDA flight-tested some AWS BL9 organic and remote engagement capabilities in FY/CY15; however, they did not conduct sufficient flight testing or analysis, using accredited M&S, to allow for an evaluation of effectiveness.

Terminal High-Altitude Area Defense (THAAD). THAAD flight testing continues to support M&S accreditation, with a few notable deficiencies. The Army Test and Evaluation Command and the BMDS Operational Test Agency conducted an independent accreditation of THAAD M&S in December 2011 using 11 previous SRBM flight tests. They accredited several models, with limitations, against simple SRBMs. Three flight tests against MRBMs, with additional information from two flight tests that flew short-range trajectories but exhibited MRBM characteristics, have allowed limited accreditation of THAAD M&S for predicting performance against MRBMs, but more testing is needed. The MDA has not conducted any THAAD flight testing against IRBM targets. M&S does not provide realistic debris scenes that are necessary to determine if debris mitigation algorithms work as expected and if THAAD can defeat larger raids.

Patriot. Patriot has collected sufficient data on most M&S to accredit them for performance evaluations. Patriot began PDB-8 developmental testing in FY/CY15. The Army conducted a PDB-8 ground test and two of the four PDB-8 developmental flight tests (the remaining two are scheduled for FY/CY16). Patriot testing in FY/CY15 did not significantly expand either the Patriot demonstrated threat set or the Patriot demonstrated battlespace.

Operational Realism

The MDA continues to incorporate aspects of operational realism into the flight test program, with FY/CY15 flight testing achieving most of the operational realism criteria developed by DOT&E and the MDA (see Table 1). Aegis BMD participated in one operational, three combined developmental/operational, and two developmental flight test events; one risk reduction flight test; and one joint U.S. Navy and MDA fleet exercise. Aegis BMD shortfalls in operational realism included (1) use of an interceptor that was not fully representative of the fielded configuration (FTM-25) and (2) use of operational fire control software that was not certified for operational test (FTX-20 and FTM-25).[14] Patriot conducted two developmental flight tests that were the first to use PDB-8 software. Because the tests were developmental tests, Patriot did not attempt to meet all of the operational realism criteria. At the BMDS level, the MDA conducted two operational flight tests, FTO-02 Event 2a that included Aegis BMD and THAAD, and FTO-02 Event 1a that included the Aegis Ashore Missile Defense Test Complex at the Pacific Missile Range Facility in Barking Sands, Hawaii. These operational tests met all tested operational realism criteria except for tactics, techniques, and procedures. During the operational tests, the C2BMC sensor managers and Aegis BMD warfighters did not fully exercise their operational doctrine.

[14] The SM-3 flown in FTM-25 did not include the Threat Update software that is included in production representative SM-3 Block IB missiles.

Table 1. Operational Realism Ratings for FY/CY15 Flight Tests

Operational Realism Criteria	Aegis BMD								Patriot		BMDS	
	FTX-20	FTM-25	FTX-19	SCD CTV-01	MMW E1/E2	ASD-15	SDC CTV-02	FTO-02 E1a CTV	P8-2	P8-4	FTO-02 E2a	FTO-02 E1a
Operationally Representative Interceptor(s)	NT	P	NT	DT	A	A	DT	A	A	A	A	A
Threat-Representative Target(s)	P	A	A	NT	A	A	NT	NT	A	A	A	A
Complex Countermeasures	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT
Operational Sensor(s)	A	A	A	NT	A	A	NT	A	A	A	A	A
Operational Fire Control Software	P	P	A	DT	A	A	DT	A	A	A	A	A
Tactics, Techniques, and Procedures	A	A	A	DT	A	DT	DT	A	A	A	P	P
Warfighter Participation	A	A	A	NT	A	A	NT	A	NT	NT	A	A
Unannounced Target Launch	A	A	A	NT	A	NT	NT	NT	NT	NT	A	A
End-to-End Test	NT	A	NT	NT	A	A	NT	NT	A	A	A	A

Key: A – Achieved, P – Partially Achieved, NT – Not Tested, DT – Developmental Test

Acronyms: ASD – At-Sea Demonstration; CTV – Controlled Test Vehicle; FTM – Flight Test Standard Missile; FTO – Flight Test Operational; FTX – Flight Test Other; MMW – Multi-Mission Warfare; SCD – SM-3 Cooperative Development

Since the advent of the DOT&E/MDA operational realism criteria in FY05, the regional/theater combat systems have achieved greater operational realism in their intercept flight tests. However, GMD has not made similar progress (see Table 2). Since the FTG-06 intercept failure in FY10, the MDA has focused much of their efforts on addressing the shortcomings uncovered during this test, which partially accounts for the lesser degree of operational realism in GMD. The MDA has not incorporated complex countermeasures into any BMDS testing.

Table 2. Operational Realism Assessment (Percentage of Times a Category Was Rated "Achieved") for Past Intercept Flight Tests against Ballistic Missiles

Operational Realism Criteria	GMD	Aegis BMD	THAAD	Patriot	BMDS
	7 Total Tests	22 Total Tests	7 Total Tests	23 Total Tests	4 Total Tests
Operationally Representative Interceptor(s)	86% (6 Tests)	77% (17 Tests)	57% (4 Tests)	91% (21 Tests)	100% (4 Tests)
Threat-Representative Target(s)	14% (1 Test)	91% (20 Tests)	100% (7 Tests)	96% (22 Tests)	100% (4 Tests)
Complex Countermeasures	0% (0 Tests)	0% (0 Tests)	0% (0 Tests)	0% (0 Tests)	0% (0 Tests)
Operational Sensor(s)	43% (3 Tests)	95% (21 Tests)	29% (2 Tests)	100% (23 Tests)	100% (4 Tests)
Operational Fire Control Software	86% (6 Tests)	73% (16 Tests)	29% (2 Tests)	100% (23 Tests)	100% (4 Tests)
Tactics, Techniques, and Procedures	43% (3 Tests)	73% (16 Tests)	57% (4 Tests)	100% (23 Tests)	50% (4 Tests)
Warfighter Participation	71% (5 Tests)	95% (21 Tests)	71% (5 Tests)	78% (18 Tests)	100% (4 Tests)
Unannounced Target Launch	57% (4 Tests)	77% (17 Tests)	57% (4 Tests)	4% (1 Test)	100% (4 Tests)
End-to-End Test	43% (3 Tests)	91% (20 Tests)	71% (5 Tests)	96% (22 Tests)	100% (4 Tests)

Demonstrated Testing

As in previous DOT&E BMDS Assessment reports since FY/CY12, DOT&E assesses the demonstrated autonomous BMDS system capability using six levels. These levels, defined in Table 3, address the maturity, complexity, and rigor of testing.

Table 3. Demonstrated Testing Level Definitions

<table>
<tr><th rowspan="2">Level</th><th colspan="4">Description of Key Characteristics</th></tr>
<tr><th>Accreditation of M&S</th><th>Demonstrated Capability</th><th>Hardware/Software Components</th><th>Testing Rigor</th></tr>
<tr><td rowspan="2">6</td><td colspan="4">Autonomous BMDS system capability verified through integrated, operational flight testing, and independently-accredited ground testing and/or models and simulations. The comprehensive set of defined weapon element requirements have been tested, and the combat system can be fully integrated into the BMDS. A credible and sustained combat capability has been demonstrated.</td></tr>
<tr><td>Independent Accreditation</td><td>Comprehensive</td><td>Full Operational Set with BMDS Integration</td><td>Integrated OT</td></tr>
<tr><td rowspan="2">5</td><td colspan="4">Broad, but incomplete, demonstration of autonomous BMDS system capabilities through independently-accredited ground testing and/or models and simulations. Accreditation is possible only if a sufficient quantity and quality of operational flight test data have been collected to support model verification and validation.[15] Limited combat operations capability has been demonstrated.</td></tr>
<tr><td>Independent Accreditation</td><td>Broad but Incomplete</td><td>Full Operational Set</td><td>OT</td></tr>
<tr><td rowspan="2">4</td><td colspan="4">Specific, limited combat system capabilities demonstrated through operationally realistic intercept flight testing with the full set of operational components. Flight testing emphasizes OT objectives over DT objectives (denoted dt/OT). Ground testing and/or models and simulations need not be independently accredited and may be used for preliminary assessments. Emergency combat operations capability has been demonstrated.</td></tr>
<tr><td>Limited Accreditation</td><td>Specific/Limited/Operationally Realistic</td><td>Full Operational Set</td><td>Combined dt/OT</td></tr>
<tr><td rowspan="2">3</td><td colspan="4">Specific, limited autonomous BMDS system capabilities demonstrated through flight testing with key operational components. Flight testing emphasizes developmental test objectives over OT objectives (denoted DT/ot). Flight test data obtained are expected to contribute to independent accreditation of models and simulations used for assessing performance.</td></tr>
<tr><td>No Accreditation Required</td><td>Specific/Limited</td><td>Key Operational Set</td><td>Combined DT/ot</td></tr>
<tr><td rowspan="2">2</td><td colspan="4">Specific combat system capabilities demonstrated through developmental flight testing with developmental or legacy system hardware/software. The flight test data obtained support the development of engineering versions of models and simulations.</td></tr>
<tr><td>Engineering M&S</td><td>Specific</td><td>Developmental or Legacy</td><td>DT</td></tr>
<tr><td rowspan="2">1</td><td colspan="4">Autonomous BMDS system concept defined with capabilities estimated through analysis, laboratory testing, and/or legacy system models and simulations.</td></tr>
<tr><td>Legacy M&S</td><td>Concept Only</td><td>Analysis, Laboratory, or Legacy</td><td>Laboratory</td></tr>
</table>

[15] Verification is the process of determining that a model or simulation implementation accurately represents the developer's conceptual description and specifications. Validation is the process of determining the degree to which a model or simulation is an accurate representation of the real world from the perspective of the intended uses of the model.

M&S – modeling and simulation; DT – developmental testing; OT – operational testing

Figures 1 and 2 show the evolution over the past five years of the capability of the autonomous BMDS systems demonstrated through testing. Aegis BMD 4.0, AWS BL9.1, THAAD 2.0, and Patriot PDB-7 are the most recently deployed or deployable combat systems providing BMDS capabilities against SRBMs and MRBMs. All of these systems have completed enough testing to attain a Level 4 or higher rating.[16] Aegis BMD 4.0, AWS BL9.1, THAAD 2.0, and GMD GS6B2.2 provide capabilities to defend against SRBM to IRBM threats.[17] Only GMD is designed to defend against ICBMs and relatively little testing has occurred against these longer-range threats (see Figure 2).

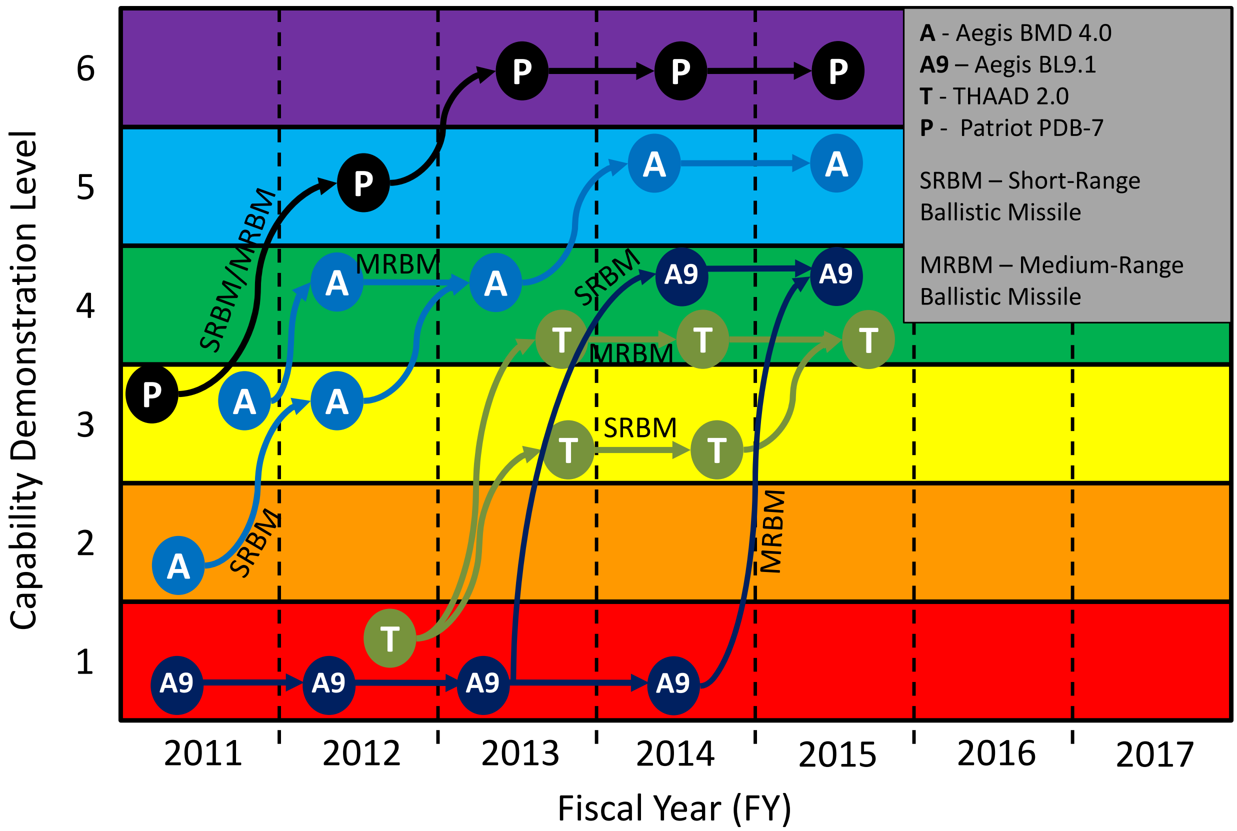

Figure 1. Demonstrated Testing for SRBMs and MRBMs

16 The MDA conducted most of their flight testing using SRBM targets, vice MRBMs.

17 GS stands for Ground System. GS6B2.2 refers to the GMD software build.

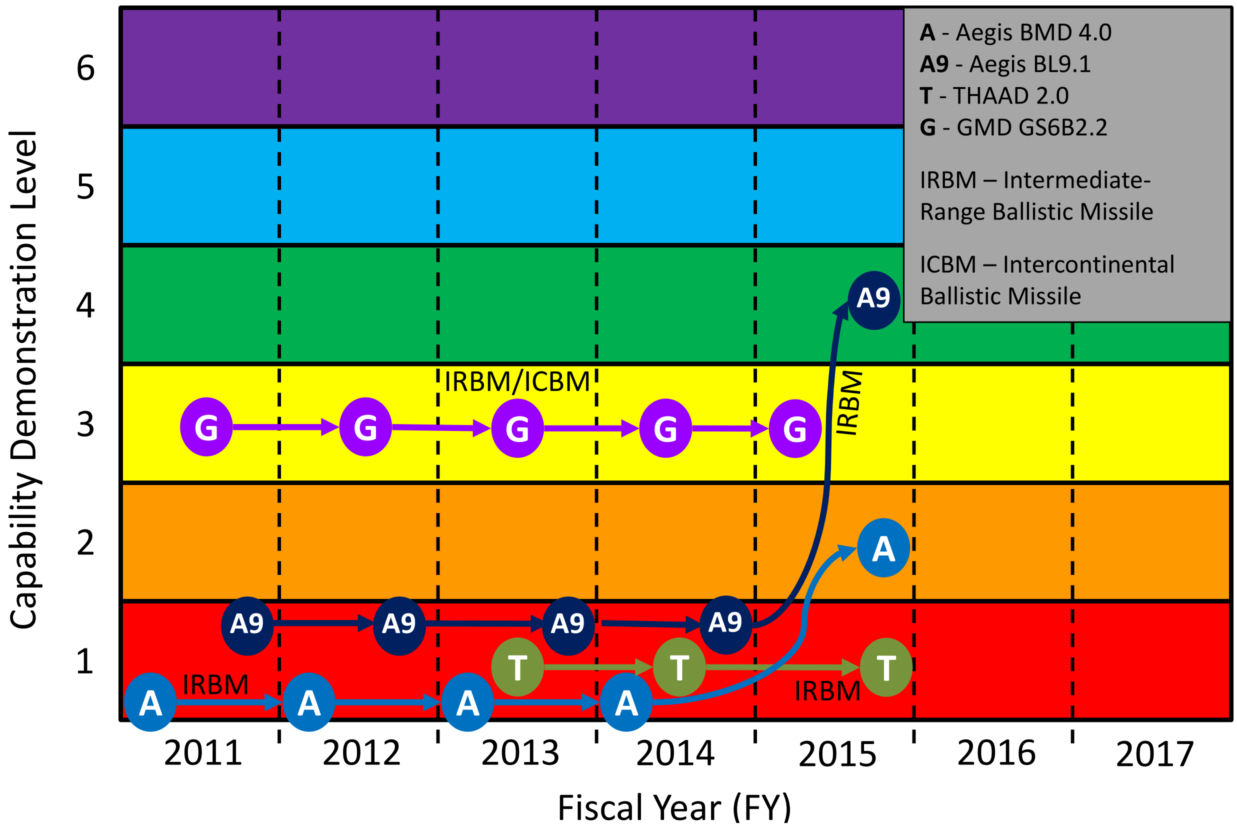

Figure 2. Demonstrated Testing for IRBMs and ICBMs

The major changes in this year's assessment are increases in the capability demonstration levels of AWS BL9.1 versus MRBMs and IRBMs, Aegis BMD 4.0 versus IRBMs, and THAAD versus SRBMs. The overall maturity, complexity, and rigor of the GMD system versus IRBM and ICBM demonstrated testing has not increased over the last five years due to deficiencies uncovered during three prior failed intercept attempts. Conversely, the maturity, complexity, and rigor of SRBM and MRBM demonstrated testing for the regional/theater combat systems have generally shown improvement over the last five years.

Recommendations

The classified Executive Summary for this report provides the full list of DOT&E recommendations that the MDA (or the Navy or Army, in some cases, for Aegis BMD, THAAD, and Patriot) should take action on to improve the operational effectiveness, suitability, survivability, and test adequacy of the BMDS and its autonomous BMDS systems. Unclassified recommendations of particular importance from the full list are as follows:[18]

[18] Many of these unclassified recommendations are also found in previously published DOT&E Annual Reports, which summarize the operational test and evaluation activities of the Department of Defense for a given fiscal year. These DOT&E Annual Reports satisfy the provisions of Title 10, United States Code, Section 139.

BMDS

The MDA should:

- Increase the development priority and associated funding for the BMDS simulation-based performance assessment capability, and work to achieve accreditation of BMDS models and simulations. This will enable quantitative performance assessments of the BMDS.
- Develop and implement integrated BMDS-level training in formal warfighter certification plans.
- Publish a comprehensive BMDS cybersecurity document that delineates the strategy for effective cybersecurity, achievable milestones for implementing the strategy, and stakeholder roles and responsibilities.
- Assess the performance of the BMDS in both flight and ground testing using realistic Link 16 loading and network configurations.
- Involve multiple BMDS systems, including Patriot, whenever possible in flight testing, in order to realistically test interoperability during live operations.
- Include the situational awareness tools used by the fire coordination and link management officers in their assessment of BMDS performance and ensure that warfighter involvement in testing is reflective of CCMD operations.
- Include reliability, maintainability, availability, and supportability data collectors for all participating elements in operationally realistic flight and ground test events to ensure that sufficient reliability, maintainability, availability, and supportability data are collected to allow for an assessment of operational suitability for all BMDS elements and sensors.
- Use targets with threat-representative reactive payloads in some future flight testing to improve the evaluation of lethality, sensor loading, battle management, and kill assessment.

GMD

The MDA should:

- Continue to extend the principles and recommendations contained in the MDA's Independent Expert Panel assessment report on the GBI fleet to all components of the BMDS instantiation for U.S. Homeland Defense.[19]
- Improve and demonstrate the reliability and availability of the operational GBIs. Specifically, the MDA should systematically upgrade fielded EKVs until the planned Redesigned Kill Vehicle can be developed and fielded.[20]

---

19 "Ground-based Midcourse Defense Fleet Assessment/Independent Expert Panel Final Report," March 3, 2014.

- Test a CE-I EKV-equipped GBI in the more stressing EKV fly-out environment to demonstrate CE-I EKV capability to accomplish the FTG-07 (FY13) test objectives and to provide validation data for M&S of CE-I EKV performance.[21]
- Increase emphasis on GMD survivability testing, including cybersecurity. Tests, demonstrations, and exercises to acquire additional survivability data should be planned for inclusion in the BMDS IMTP.

Aegis BMD 4.0 and AWS BL9.1

The MDA and the Navy should:

- Publish tailored maintenance procedures for the Aegis Ashore Missile Defense System.
- Use the industry-led failure review board process to identify the root cause of the low cold gas pressure anomalies from recent lot acceptance testing of the SM-3 Block IB cold gas regulator, and determine the appropriate corrective actions needed to ensure proper functioning of that SM-3 component.
- Ensure that sufficient flight testing of the Aegis BMD 4.0 and AWS BL9.B1/C1 systems is conducted to allow for accreditation of the M&S suites over the expected engagement battlespace for real-world engagement scenarios.
- Perform high-fidelity M&S analysis over the expected AWS BL9.B1/C1 engagement battlespace for EPAA Phase 2 to allow for a broad quantitative evaluation of engagement capability.
- Perform an end-to-end flight test demonstration of an Aegis BMD 4.0 or BL9 launch-on remote-remote functionality (where external radar data are used throughout the engagement), to better prove the efficacy of this capability.
- Conduct operationally realistic testing that exercises the improved engagement coordination of Aegis BMD 4.0 with THAAD and Patriot. FTO-03 Event 2 (FY18) is planned to demonstrate this capability.
- Conduct sufficient ground and flight testing of the re-designed SM-3 Block IB TSRM nozzle after completion and installation of the new design concept to confirm the reliability of the new design under the most stressing operational flight conditions. Interceptor-only flight testing in 2016 is expected to address this recommendation.

---

[20] In 2015, the MDA replaced the eight fielded GBIs that were equipped with the CE-II EKVs with new GBIs that incorporate an EKV inertial measurement unit cradle, and upgraded the EKV firmware to mitigate possible EKV vibration-induced failures like those that caused the interceptor failure in FTG-06a. In 2016, the MDA plans to field eight additional GBIs that will be equipped with CE-II EKVs.

[21] The MDA is planning to test a GBI that is equipped with a CE-I IEV in a more stressing EKV fly-out environment in FTG-11 (FY17). FTG-11 may be adequate to satisfy this recommendation if the GBI fly-out range and the closing velocity in FTG-11 are comparable to those in FTB-07.

- Conduct flight testing of the AWS BL9 system while operating in Integrated Air and Missile Defense radar priority mode to perform ship self-defense against multiple anti-ship cruise missiles while engaging a raid of ballistic missile threats.
- Conduct high-fidelity M&S or hardware-in-the-loop events with integrated six degree-of-freedom models for raid scenarios up to the design limit to better assess raid engagement performance.

THAAD

The MDA and the Army should:

- Improve THAAD training to ensure that THAAD operators are prepared to use the system in combat.[22]
- Improve launcher reliability, particularly the 3-kilowatt generators.
- Implement THAAD equipment redesigns and modifications identified during natural environment testing to prevent problems seen in testing. Some, but not all, of these deficiencies have been addressed by hardware modifications included in THAAD 2.0.
- Conduct flight testing with Patriot to demonstrate automatic engagement coordination and debris mitigation algorithms.
- Rigorously test THAAD 2.0 given the large number of obsolescence redesigns of hardware and software and the impact they had during FTO-02 Event 2a.
- Flight test THAAD against an IRBM target as soon as possible. The demonstration that had been planned for FY15 (Flight Test THAAD-18, or FTT-18) has been rescheduled for 3QFY17.
- Demonstrate the use of approved THAAD documentation to verify the accuracy and completeness of the documentation.[23]
- Conduct an updated cybersecurity assessment as soon as possible.
- Conduct Electronic Warfare testing and analysis.

---

[22] The materiel release process tracks the resolution of training deficiencies and, to date, the MDA has made good progress. Full resolution, however, is not scheduled until the end of FY18. Because of the magnitude of these problems, DOT&E will retain this as a recommendation until the warfighters implement all of the resolution plans and deem them satisfactory.

[23] The Army closed a materiel release condition that implemented a process to ensure documentation is properly corrected when problems are found, but the condition does not ensure that a final version of the documentation is acceptable. DOT&E will retain this recommendation until documentation errors found during testing are minimal.

Patriot

The Army should:

- Improve Patriot radar reliability.
- Improve Patriot training to ensure that Patriot operators are prepared to use the system in combat.
- Conduct a Patriot flight test against an anti-radiation missile target to validate models and simulations.
- Include Patriot in integrated BMDS operational flight testing to demonstrate Patriot-to-THAAD automatic engagement coordination, Patriot-to-Aegis BMD manual or automatic engagement coordination, and the capability of Patriot to engage threats that are engaged but not intercepted by THAAD or Aegis BMD.

C2BMC

The MDA should:

- Continue C2BMC development efforts to provide an engagement management capability to the BMDS.
- Perform a flight test with multiple AN/TPY-2 (FBM) radars to assess the ability of C2BMC to correctly task and fuse track data from multiple sources observing realistic targets and to assess the ability to disseminate the subsequent system-level data across the BMDS.
- Evaluate BMDS performance in dual radar missions, particularly Defense of Europe for USEUCOM and U.S. Homeland Defense for USNORTHCOM, using the COCOM suite (which can only manage one radar), when the C2BMC Global Engagement Manager is non-mission capable.
- Use ground testing to evaluate the ability of the BMDS to effectively operate when C2BMC capability is degraded.

J. Michael Gilmore
Director

DEPARTMENT OF DEFENSE

UNITED STATES OF AMERICA