

## Aegis Ballistic Missile Defense (Aegis BMD)

### Executive Summary

- The Aegis Ballistic Missile Defense (BMD) program conducted one intercept mission in FY14 and one in early FY15. Two ballistic missile targets were intercepted, and two anti-air warfare targets were engaged.
- In FY14, Aegis BMD completed the IOT&E flight test program for the Aegis BMD 4.0 system and Standard Missile-3 (SM-3) Block IB guided missile, in accordance with the DOT&E-approved Integrated Master Test Plan.
- The final IOT&E flight test was a successful intercept of a medium-range ballistic missile, and was the fifth successful intercept of the Aegis BMD 4.0/SM-3 Block IB system.
- In the first live fire event using Aegis Baseline 9.B0 (i.e., Aegis BMD 5.0), Aegis Ashore (a future land-based component of the European Phased-Adaptive Approach (EPAA)) demonstrated a capability to fire, control, establish uplink/downlink communication, provide guidance commands, and provide target information to an SM-3 Block IB guided missile.
- The Aegis BMD program continued testing of the Aegis BMD 5.0 system (Capability Upgrade version, Baseline 9.C1) by conducting two tests in early FY15: a simulated engagement of a medium-range ballistic missile and a live intercept of a short-range ballistic missile while simultaneously engaging a raid of two subsonic cruise missiles.
- Aegis BMD continued to improve interoperability with other Ballistic Missile Defense System (BMDS) elements and sensors during flight and ground testing in FY14.
- Hardware-in-the-loop (HWIL) ground testing demonstrated Aegis BMD capability to contribute to theater, regional (including EPAA), and strategic-level defense missions spanning a range of ballistic missile defense scenarios.

### System

- Aegis BMD is a sea-based missile defense system that employs the multi-mission shipboard Aegis Weapon System, with improved radar and new missile capabilities to engage ballistic missile threats. Capabilities of Aegis BMD include:
  - Computer program modifications to the AN/SPY-1 radar for long-range surveillance and track (LRS&T) of ballistic missiles of all ranges.
  - A modified Aegis Vertical Launching System, which stores and fires SM-3 Block IA and Block IB guided missiles (on select ships), and modified SM-2 Block IV guided missiles (on select ships).
  - SM-3 Block IA and Block IB guided missiles, which use a maneuverable kinetic warhead to accomplish midcourse engagements of short-, medium-, and intermediate-range ballistic missiles.
  - Modified SM-2 Block IV guided missiles, which provide terminal engagement capability against short-range ballistic missiles.



- Aegis Ashore is a land-based version of Aegis BMD, with an AN/SPY-1 radar and Vertical Launching System to enable engagements against medium- and intermediate-range ballistic missiles with SM-3 guided missiles. Once it is deployed to Romania in 2015, Aegis Ashore will become the central, land-based component of the second phase of the EPAA for the defense of Europe.
- Aegis BMD and Aegis Ashore are capable of performing autonomous missile defense operations and operations that exploit networked sensor information; they can send/receive cues to/from other BMDS sensors through tactical datalinks.

### Mission

The Navy can accomplish three missile defense-related missions using Aegis BMD:

- Defend deployed forces and allies from short- to intermediate-range theater ballistic missile threats
- Provide forward-deployed radar capabilities to enhance defense against ballistic missile threats of all ranges by sending cues or target track data to other elements of the BMDS
- Provide all short- to long-range ballistic missile threat data to the Command and Control, Battle Management, and Communications (C2BMC) system for dissemination to Combatant Commanders' headquarters to ensure situational awareness

### Major Contractors

- Aegis BMD Weapon System: Lockheed Martin Corporation, Mission Systems and Training – Moorestown, New Jersey
- AN/SPY-1 Radar: Lockheed Martin Corporation, Mission Systems and Training – Moorestown, New Jersey
- SM-3 Missile: Raytheon Company, Missile Systems – Tucson, Arizona

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## Activity

- The MDA completed the IOT&E flight-testing phase for Aegis BMD 4.0 and SM-3 Block IB guided missiles with the conclusion of Flight Test Standard Missile-21 (FTM-21) (FY13), FTM-22, and Flight Test Other-18 (FTX-18). All flight testing was accomplished in accordance with the DOT&E-approved Integrated Master Test Plan.
- The Aegis BMD program executed modeling and simulation runs-for-the-record in FY14 to supplement flight test data and aid in the assessment of Aegis BMD 4.0 system effectiveness. DOT&E published a classified IOT&E report on Aegis BMD 4.0 and SM-3 Block IB operational effectiveness and operational suitability in December 2014 to support the Full-Rate Production decision for SM-3 Block IB missiles. The Full-Rate Production decision is planned for FY15.
- Although the program completed FOT&E for the Aegis BMD 3.6.1 system in FY11, the program continued to use variants of the Aegis BMD 3.6 system (i.e., 3.6.1 and 3.6.3) in BMDS-level tests in FY14 to assess system-level engagement capability and interoperability.
- The Aegis BMD program conducted one intercept mission in FY14 and one in early FY15. Two ballistic missile targets were intercepted, and two anti-air warfare targets were engaged.
  - During FTM-22 in October 2013, an Aegis BMD 4.0.2 cruiser intercepted a medium-range, separating target with an SM-3 Block IB guided missile. The FTM-22 engagement was the fifth successful intercept mission conducted with the Aegis BMD 4.0 system with an SM-3 Block IB guided missile, and the second of two IOT&E flight test missions (the other being FTM-21 in September 2013). The FTM-22 engagement was also the first intercept of a medium-range target with the Aegis BMD 4.0 system and an SM-3 Block IB guided missile.
  - FTM-25 in November 2014 was an integrated air and missile defense mission wherein an Aegis Baseline 9.C1 (i.e., Aegis BMD 5.0 with Capability Upgrade) destroyer in integrated air and missile defense priority mode detected, tracked, and performed an SM-3 Block IB intercept of a short-range ballistic missile, while simultaneously conducting an anti-air warfare raid engagement against two subsonic cruise missile surrogates.
- Aegis BMD ships and Aegis Ashore participated in simulated engagements using live targets, a controlled vehicle test with a live interceptor, and a multi-element test event with the AN/SPY-1 radar acting as a forward-based sensor in FY14.
  - During FTX-18 in January 2014, an Aegis BMD 4.0.2 destroyer detected, tracked, and conducted simulated SM-3 Block IB engagements against three, short-range ballistic missile targets in a raid scenario. FTX-18 was the last of three Aegis BMD 4.0 IOT&E test missions. An Aegis BMD 3.6.1 ship and Aegis Ashore (Aegis Baseline 9 Lab at Surface Combat Systems Center, Wallops Island, Virginia) also participated in FTX-18 for data collection purposes and to exercise simulated engagements using remote data sent from the Aegis BMD 4.0.2 ship.
  - In May 2014, Aegis Ashore Control Test Vehicle-01 (AACTV-01) demonstrated the capability of the Aegis Ashore test site at the Pacific Missile Range Facility to fire, control, establish uplink/downlink communication, provide guidance commands, and provide target information to an SM-3 Block IB guided missile. AACTV-01 was the first live fire event using Aegis Baseline 9.B0 (i.e., Aegis BMD 5.0) and the first SM-3 guided missile firing from Aegis Ashore.
  - In June 2014, an Aegis BMD 3.6.1 destroyer participated in Flight Test Ground-Based Interceptor-06b (FTG-06b) to provide LRS&T support to the Ground-Based Midcourse Defense (GMD) system. The ship acquired the intermediate-range ballistic missile target and transmitted track information over Link 16 to support the generation of GMD's weapon task plan and a cue to the Sea-Based X-band radar.
  - In Flight Test Other-20 (FTX-20) in October 2014, a destroyer with Aegis Baseline 9.C1 software conducted a simulated SM-3 Block IB engagement of a separating medium-range ballistic missile.
- In FY14, Aegis BMD ships and HWIL facilities also participated in several flight and ground tests to assess Aegis BMD 4.0.2 and 3.6.1/3.6.3 system functionality and interoperability with the BMDS.
  - Ground Test Integrated-04e (GTI-04e) Part 1a runs-for-the-record in October 2013 explored theater/regional defense capabilities (beyond those tested in GTI-04e Part 1 in FY13) using updated software builds for AN/TPY-2 (Forward Based Mode (FBM)), C2BMC, and Terminal High-Altitude Area Defense (THAAD), in addition to Aegis BMD 4.0.2 and 3.6.3.
  - Aegis BMD participated in Fast Phoenix in December 2013, which the Missile Defense Agency (MDA) executed in the U.S. Pacific Command area of responsibility, while simulating U.S. European Command and U.S. Central Command interoperability architectures. The test's purpose was to assess a new communications architecture between Aegis BMD ships using the Link Monitoring Management Tool and C2BMC S6.4 Maintenance Release 2. Fast Phoenix used both operational and HWIL assets and operational communications.
  - GTI-04e Part 2 in April and May 2014 tested the engagement capabilities of fielded and to-be-fielded missile defense elements and sensors against ballistic missiles of all ranges in a HWIL environment. Participants included Aegis BMD 4.0.2 and 3.6.3 (laboratory sites), C2BMC, Patriot, THAAD, Space-Based Infrared System, AN/TPY-2 (FBM), and GMD.
  - Fast Fire, which the MDA conducted as part of GTI-04e Part 2 in May 2014, tested the capability of Aegis BMD 4.0.2 to support its designed-to maximum number of simultaneous ballistic missile and anti-air warfare engagements and control all standard missiles in those

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engagements. An AN/TPY-2 (FBM) radar provided forward-based radar data to support the engagements.

- Aegis BMD participated in Fast Exchange in both HWIL (June 2014) and distributed (August 2014) representations to assess cross-Area of Responsibility engagements. Additional participants included AN/TPY-2 (FBM), THAAD, Patriot, C2BMC, and Space-Based Infrared System.
- Early developmental testing of the SM-3 Block IIA guided missile began in FY14.
  - In October 2013, the SM-3 Cooperative Development Propulsion Test Vehicle-01 (SCDPTV-01) flight test fired an SM-3 Block IIA guided missile. The missile included a live Mk 72 Mod 2 booster with an inert 21-inch-diameter mass equivalent upper-stage assembly in the Mk 29 Mod 0 lightweight canister, specifically developed for the SM-3 Block IIA guided missile. All assets under test performed as designed. SCDPTV-01 was a follow-on test from a restrained firing conducted in FY13, and the second of a series of six test events to validate missile and canister designs of the next variant of the SM-3.

## Assessment

- Flight testing and supporting modeling and simulation demonstrated that Aegis BMD 4.0 has the capability to engage and intercept non-separating, simple-separating, and complex-separating ballistic missiles in the midcourse phase with SM-3 Block IB guided missiles. However, flight testing and modeling and simulation did not test the full range of expected threat types, threat ground ranges, and threat raid sizes. Details can be found in the classified December 2014 Aegis BMD IOT&E Report.
- Reliability and maintainability data from FY14, in combination with data collected during a maintenance demonstration and previous flight testing, suggest that overall Aegis BMD 4.0 Weapon System availability is adequate for the midcourse defense mission against short- and medium-range ballistic missiles. Testing showed that improvements in Aegis BMD hardware reliability are needed, although the impact on operational availability was not significant due to the low repair times.
- The limited number of SM-3 Block IB firings (nine) and the two, third-stage rocket motor (TSRM) failures (FTM-16 Event 2 in FY11 and the second missile failure in FTM-21 in FY13) lower certainty in overall SM-3 Block IB missile reliability. The program addressed and tested a correction for the first of the SM-3 TSRM problems when it modified the TSRM's inter-pulse delay time. The Aegis BMD program has exercised the new inter-pulse delay without incident in three flight tests and a number of ground-based static firings. The correction, however, did not prevent the TSRM failure in the second of two salvo-launched SM-3 Block IB guided missiles in FTM-21, which also suffered a reliability failure of the TSRM aft nozzle area during second pulse operations of the two-pulse motor (the first missile had already achieved a

successful intercept). The MDA established a Failure Review Board (FRB) to determine the root cause of this failure and the Board has uncovered enough evidence to determine that a re-design is needed for the TSRM nozzle. The program has a preliminary design for the new nozzle, and began the ground testing of new design concepts in FY14. The new design will be retrofittable into current SM-3 Block IA and Block IB missiles.

- Flight testing and modeling and simulation have demonstrated the Aegis BMD 4.0 capability to perform the LRS&T mission, albeit with only a single threat. Additionally, the FTG-07 mission in FY13 highlighted the need to further explore and refine tactics, techniques, and procedures (TTPs) for the transmission and receipt of Aegis BMD track data for GMD use.
- Testing of the Aegis BMD 4.0 system did not evaluate automated engagement coordination in flight testing; due to lack of ship availability. However, the MDA tested it during Ground Test Focused-04e and it will be operationally tested during FOT&E.
- The program demonstrated that Aegis Ashore can fire, detect, and control an SM-3 Block IB guided missile during AACTV-01. This is an important first step toward proving that Aegis Ashore can perform missile defense operations similar to those on an Aegis BMD ship for the defense of Europe as part of EPAA Phase 2. An engagement of a ballistic missile target by Aegis Ashore will take place in Event 1 of Flight Test Operational-02 (FTO-02) in FY15.
- During FTX-20, an Aegis Baseline 9.C1 destroyer (Aegis BMD 5.0 with Capability Upgrade) successfully detected, tracked, and conducted a simulated engagement of a separating medium-range ballistic missile target.
- During FTM-25, an Aegis Baseline 9.C1-configured destroyer, operating in integrated air and missile defense priority mode, intercepted a short-range ballistic missile target using an SM-3 Block IB guided missile while simultaneously engaging two subsonic cruise missile targets using two SM-2 Block IIIA missiles.
- The MDA continues to utilize Aegis BMD ships and HWIL representations of the Aegis BMD 4.0 and 3.6 variants, which has helped to refine TTPs and overall interoperability of the system with the BMDS. However, the test events routinely demonstrated that inter element coordination and interoperability are still in need of improvement.

## Recommendations

- Status of Previous Recommendations.
  - The program has not addressed the first two recommendations (out of five) from FY13 to conduct:
    - Flight testing of the Aegis BMD 4.0 remote authorized engagement capability against a medium-range ballistic missile or intermediate-range ballistic missile target using an SM-3 Block IB guided missile. FTO-02 Event 2, scheduled for 4QFY15, is planned to demonstrate this capability

- Operationally realistic testing that exercises Aegis BMD 4.0's improved engagement coordination with THAAD and Patriot
- The program addressed the third recommendation from FY13 to continue to assess an Aegis BMD 4.0 intercept mission during which the ship simultaneously engages an anti-air warfare target to verify BMD/anti-air warfare capability, when it conducted the FTM-25 mission using Aegis Baseline 9.C1.
- The program partially addressed the fourth recommendation from FY13 to use the FRB process to identify the failure mechanism responsible for the FTM-21 second missile failure and determine the underlying root cause that may be common to both the FTM-16 Event 2 and FTM-21 second missile failures. The MDA established an FRB following FTM-21 and, although it is still ongoing, preliminary findings from the FRB have pointed to a similar root cause, prompting the program to begin a re-design of the TSRM nozzle.
- The program partially addressed the fifth recommendation from FY13 to deliver sufficient Aegis BMD 4.0 validation data and evidence to support BMDS modeling and simulation verification, validation, and accreditation (VV&A) of the Aegis HWIL and digital models. They did so when the Commander, Operational Test and Evaluation Force provided VV&A evidence for the digital models used for element-level performance analyses in support of the operational assessment of the Aegis BMD 4.0 system with SM-3 Block IB guided missiles. Aegis BMD provided V&V data from element post-flight reconstruction events for FTM-16 Event 2, FTM-18, and FTM-21, based on BMDS Operational Test Agency performance parameters and acceptability criteria as evidence supporting accreditation of Aegis BMD HWIL models participating in BMDS level ground testing. The BMDS Operational Test Agency is reviewing the data for an accreditation recommendation.
- FY14 Recommendations. The program should:
  1. Conduct flight tests or high-fidelity modeling and simulation analyses to demonstrate the Aegis BMD 4.0 system's capability to perform LRS&T of a raid of long-range threats.
  2. Determine the appropriate LRS&T TTPs for the transmission and receipt of Aegis BMD 4.0 track data for GMD use.
  3. Ensure that sufficient flight testing of the Aegis Baseline 9.C1 system is conducted to allow for VV&A of the modeling and simulation suite to cover the full design to Aegis BMD battlespace of threat ballistic missiles.
  4. 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 prove the new design works under the most stressing operational flight conditions.