

## Aegis Ballistic Missile Defense (Aegis BMD)

### Executive Summary

- The Missile Defense Agency (MDA) conducted four Aegis Ballistic Missile Defense (BMD) intercept flight tests in FY/CY18. Aegis BMD successfully intercepted three of the four ballistic missile targets in those tests. The Standard Missile-3 (SM-3) Block IB variant was successful in two of these tests. The SM-3 Block IIA variant succeeded in one test and failed in another.
- Aegis BMD participated in five non-intercept flight tests in FY/CY18 with simulated SM-3 Block IB and Block IIA variants engaging live targets and a live SM-6 Dual I missile engaging a simulated target.
- Aegis BMD provided hardware-in-the-loop (HWIL) representations for four Ballistic Missile Defense System (BMDS) ground tests that provided information on Aegis BMD interoperability and weapon system functionality in various regional/theater and strategic scenarios.
- The MDA delivered high-fidelity digital modeling and simulation (M&S) runs for record (RFRs) results in FY18 to support assessments of Aegis Baseline (BL) 9.C1 and SM-3 Block IB Threat Update (TU) missile performance for select scenarios.

### System

- Aegis BMD is a sea- and land-based missile defense system that employs the multi-mission shipboard Aegis Weapon System, with improved radar and new missile capabilities to engage ballistic missile and anti-air warfare (AAW) threats. Aegis BMD includes:
  - Computer program modifications to all Aegis Weapon System elements, including the AN/SPY-1 radar, to support multiple BMDS mission capabilities including long-range surveillance and track, engagement support surveillance and track, and organic engagement with the SM-3, SM-6, or modified SM-2 Block IV missile variants against ballistic missiles
  - A modified Aegis Vertical Launching System, which stores and fires SM-3 Block IA, Block IB, and Block IIA guided missiles, modified SM-2 Block IV guided missiles, and SM-6 Dual I guided missiles
  - SM-3 Block IA, Block IB, and Block IIA guided missiles that use maneuverable kinetic warheads (KWs) to



accomplish midcourse engagements of short-range ballistic missiles (SRBMs), medium-range ballistic missiles (MRBMs), and intermediate-range ballistic missiles (IRBMs)

- Modified SM-2 Block IV guided missiles that provide Sea-Based Terminal (SBT) capability against SRBMs and MRBMs
- SM-6 Dual I (fielded capability) and Dual II (under development) guided missiles that provide SBT capability against SRBMs and MRBMs in their terminal phase of flight, anti-ship cruise missiles, and all types of aircraft
- Aegis BMD ships and Aegis Ashore are designed to conduct missile defense operations, send/receive cues to/from other BMDS sensors through tactical datalinks, and conduct engagements using remote track data from BMDS sensors.
- Aegis Ashore (BL 9.B1) is the current land-based version of Aegis BMD, with an AN/SPY-1 radar and Vertical Launching System to enable engagements against MRBMs and IRBMs with SM-3 guided missiles. The operational Aegis Ashore site in Romania is the land-based component of the second phase of the European Phased-Adaptive Approach (EPAA) for the defense of Europe. A second site in Poland, currently undergoing construction and scheduled for completion in 2020, will complete the third phase of the EPAA for the defense of Europe.
- The following table summarizes the Aegis BMD weapon system configurations currently deployed or under development.

# FY18 BALLISTIC MISSILE DEFENSE SYSTEMS

WEAPON SYSTEM	AEGIS BASELINE (BL) NOMENCLATURE	PLATFORM	MISSILES
Aegis BMD 5.1	BL 9.C2	Guided-Missile Destroyers (DDGs)	SM-3 Blocks IA, IB, and IIA SM-6 Dual I and Dual II SM-2 Block IV
	BL 9.B2	Aegis Ashore	SM-3 Blocks IA, IB, and IIA
Aegis BMD 5.0 (Capability Upgrade)	BL 9.C1	DDGs	SM-3 Blocks IA and IB SM-6 Dual I SM-2 Block IV
	BL 9.B1	Aegis Ashore	SM-3 Blocks IA and IB
Aegis BMD 4.1	Not Applicable	DDGs and Guided-Missile Cruisers (CGs)	SM-3 Blocks IA and IB SM-6 Dual I
Aegis BMD 4.0.3			SM-3 Blocks IA and IB SM-2 Block IV
Aegis BMD 3.6.4			SM-3 Blocks IA and IB SM-2 Block IV

## 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 BMDS elements
- Provide 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, Rotary and Mission Systems – Moorestown, New Jersey
- AN/SPY-1 Radar: Lockheed Martin Corporation, Rotary and Mission Systems – Moorestown, New Jersey
- SM-3, SM-2 Block IV, and SM-6 Missiles: Raytheon Company, Missile Systems – Tucson, Arizona

## Activity

- The MDA conducted all FY/CY18 testing in accordance with the DOT&E-approved Integrated Master Test Plan.
- The MDA conducted four Aegis BMD intercept flight tests in FY/CY18, successfully engaging three of the four ballistic missile targets:
  - During the Formidable Shield-17 (FS-17) Navy fleet exercise in October 2017, an Aegis BMD 4.0.3 destroyer intercepted an MRBM target with an SM-3 Block IB TU missile. Participating NATO naval assets intercepted three AAW targets as part of a multinational integrated air and missile defense exercise.
  - During Flight Test Standard Missile-29 (FTM-29) in January 2018, the Aegis Ashore Missile Defense Test Complex (AAMDTC) at the Pacific Missile Range Facility in Kauai, Hawaii, attempted to intercept an air-launched IRBM target with an SM-3 Block IIA missile using the Aegis BL 9.B2 Engage on Remote (EOR) capability. The system failed to achieve an intercept when the SM-3 Block IIA third stage rocket motor did not ignite. The MDA subsequently conducted a failure investigation, identified the root cause, implemented a corrective action, and demonstrated the correction through a flight test.
  - During Japanese Flight Test Mission-05 (JFTM-05) Event 2 in September 2018, a Japanese Aegis destroyer organically intercepted a simple-separating SRBM target with an SM-3 Block IB TU missile.
  - During FTM-45 in October 2018, an Aegis BL 9.C2 destroyer organically intercepted a simple-separating MRBM target with an SM-3 Block IIA missile. This was the first intercept using a production-representative SM-3 Block IIA missile, and the second Block IIA intercept overall. This flight test also demonstrated the corrective action for the previous FTM-29 missile failure.
- Aegis BMD participated in five non-intercept flight test events in FY/CY18 with SM-3 Block IB and Block IIA variants engaging live targets and a live SM-6 Dual I missile engaging a simulated target:
  - During FS-17 in October 2017, Aegis BMD 4.0.3 and Aegis BL 9.C1 destroyers conducted simulated engagements of ballistic missile targets using remote data. NATO naval assets transmitted the remote track data through C2BMC and a NATO communications gateway. NATO assets that did not participate as BMD assets fired simulated and live missiles and engaged four AAW targets.

# FY18 BALLISTIC MISSILE DEFENSE SYSTEMS

- During Standard Missile Controlled Test Vehicle-03 (SM CTV-03) in October 2017, an Aegis BMD 4.1 destroyer engaged a simulated ballistic missile target with a live SM-6 Dual I missile. The firing supports certification of the Aegis BMD 4.1 upgrade to include hosting SBT capability.
  - During Flight Test Other-33 (FTX-33) in March 2018, the AAMDTC with BL 9.B2 software detected and tracked a complex SRBM target. The AAMDTC forwarded track data to an Aegis BMD laboratory to conduct a simulated EOR engagement.
  - During the Pacific Dragon 2018 Navy fleet exercise in August 2018, the AAMDTC with BL 9.B2 software conducted a simulated SM-3 Block IIA EOR engagement against an SRBM target using track data provided by U.S. and Japanese Aegis BMD ships. Laboratory representations of Aegis BMD also conducted simulated Launch on Remote engagements using track data provided by airborne sensors.
  - During JFTM-05 Event 2 in September 2018, an Aegis BL 9.C2 destroyer conducted a simulated engagement against a simple-separating SRBM target, which served as risk reduction for FTM-45.
  - Four BMDS ground tests provided information on Aegis BMD interoperability and weapon system functionality in various regional/theater and strategic scenarios:
    - Ground Test-18 (GT-18) Sprint 1 DT RFRs in April 2018 explored BMDS performance in U.S. Indo-Pacific Command (USINDOPACOM) defense scenarios using an HWIL environment. Aegis BMD 3.6.4, 4.1, 4.0.3, and BL 9.C1 participated in the test.
    - Ground Test Integrated-07b (GTI-07b) U.S. European/Central Commands (E/C) OT RFRs in April and May 2018 examined remote engagement, surveillance, and tracking performance to support an assessment of EPAA Phase 3 using an HWIL environment. Three Aegis BMD laboratory sites and the AAMDTC participated. GTI-07b (E/C) tested Aegis BL 9.C2, BL 9.B2, BL 9.C1, BL 9.B1, BMD 3.6.4, and BMD 4.1, and supported assessments of SM-3 Block IIA and SM-6 Dual II missiles. Warfighter support included U.S. Navy Aegis BMD teams from three Aegis BMD ships, Aegis Ashore, and Commander, Operational Test and Evaluation Force (OPTEVFOR) evaluators.
    - GT-18 Sprint 2 DT RFRs in July 2018 collected developmental data in an HWIL venue to support the inclusion of the Aegis BL 9.C2 SBT Increment 2 and SM-3 Block IIA EOR capabilities into the operational capability baseline for defense of USINDOPACOM.
    - Ground Test Distributed-07b (GTD-07b) (E/C) DT/OT RFRs in August and September 2018 used a distributed environment to explore BMDS performance in theater/regional defense of USEUCOM and USCENTCOM to collect data to support deployment of EPAA Phase 3. GTD-07b (E/C) tested Aegis BL 9.C2, BL 9.B2, BL 9.C1, and BMD 4.1.
  - The BMDS Operational Test Agency and OPTEVFOR recommended accreditation of all participating Aegis BMD HWIL M&S for the regional/theater and strategic scenarios assessed ground testing, with the exception of the M&S for Aegis BMD 4.1, which was only accredited for use in GTD-07b (E/C).
  - The MDA delivered high-fidelity digital M&S RFR results in FY18 to support assessments of Aegis BL 9.C1 and SM-3 Block IB TU missile performance for select scenarios. OPTEVFOR accredited the FY17/18 RFR sets for Aegis BL 9.B1 and BL 9.C1 performance assessments.
  - A December 2017 SM-3 Block IB Acquisition Decision Memorandum requires the MDA and DOT&E to ensure periodic flight testing of the Block IB throughout the life of the program in the Integrated Master Test Plan (IMTP). The MDA has addressed this requirement by adding surveillance firings to the test program. The MDA conducted two successful end-to-end flight tests of the production-representative Block IB TU missile during FS-17 and JFTM-05 Event 2.
- ### Assessment
- Results from flight testing, high-fidelity M&S, HWIL, and distributed ground testing demonstrate that Aegis BMD can intercept non-separating, simple-separating, and complex-separating ballistic missiles in the midcourse phase. However, flight testing and M&S did not address all expected threat types, ground ranges, and raid sizes.
  - FTM-45 successfully and fully demonstrated the Aegis BL 9.2 organic engagement capability and corrective action for the previous FTM-29 missile failure. FTM-29 was only partially able to demonstrate EOR capability given the in-flight missile failure. In FTM-29, the Aegis Weapon System supported the SM-3 Block IIA missile and demonstrated bi-directional communication between the SM-3 Block IIA guidance section and the KW until loss of signal at horizon. However, the weapon system did not exercise all aspects of communication after KW eject. DOT&E considers the FTM-29 failure to be an example of a shortfall in conducting ground testing in an operationally representative way, and an example of a deficiency found in OT that DT should have discovered.
  - The MDA implemented process improvements to better identify, report, and fix common failures and anomalies identified during SM-3 ground testing prior to flight testing.
  - SM CTV-03 demonstrated the capability of the Aegis BMD 4.1 upgrade to fire an SM-6 Dual I missile. The BMD 4.1 build incorporates BL 9.C1 capabilities into the BMD 4.0 baseline.
  - FS-17 demonstrated the Aegis BMD 4.0.3 capability to interoperate with NATO partners over operational communication architectures during cruise missile and ballistic missile engagements, and to use remote data provided by NATO partners to prosecute remote engagements. JFTM-05 Event 2 demonstrated inter-ship communication between U.S. and Japanese destroyers using a realistic communications architecture while prosecuting ballistic missile engagements. Pacific Dragon demonstrated interoperability between U.S.

Aegis BMD assets, Japanese destroyers, and Republic of Korea naval assets.

- Aegis BMD has exercised rudimentary engagement coordination with Terminal High-Altitude Area Defense firing units, but not with Patriot. The MDA plans to include Patriot in FTO-03. MDA ground tests have routinely demonstrated that inter-element coordination and interoperability need improvement to increase situational awareness and improve engagement efficiency.
- The MDA has been collaborating with DOT&E and the Under Secretary of Defense (Research and Engineering) to establish an affordable ground testing approach to support assessments of reliability. DOT&E cannot assess SM-3 missile reliability with confidence until the MDA is able to provide additional ground test data that simulates the in-flight environment.

DOT&E is working with the MDA to determine if existing ground test venues are able to provide the needed missile reliability data.

## **Recommendations**

The MDA should:

1. Ensure that ground tests of all SM-3 missile components, sections, and all-up rounds use the same configuration as will be flown in flight tests (i.e., “test as you fly”).
2. Determine how to properly score acceptance ground test data for production missiles to enable their use in estimating SM-3 reliability.
3. Fund and execute high-fidelity M&S RFRs for Aegis BL 9.2 SM-3 Block IIA and SM-6 Dual II scenarios that span the engagement battlespace.