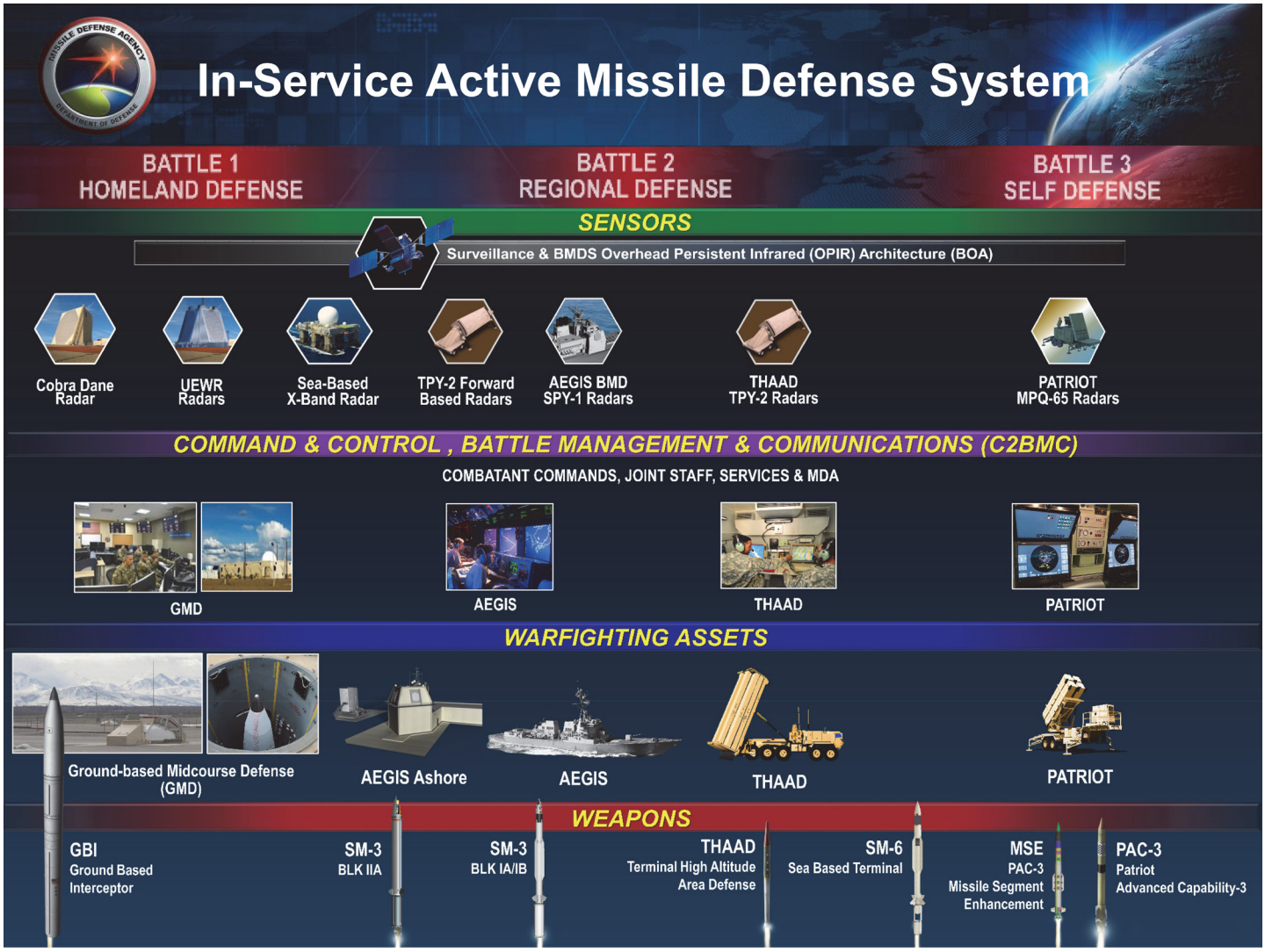
MISSILE DEFENSE SYSTEM



BMD - Ballistic Missile Defense
BLK - Block
MPQ - Mobile, Position Locating, Special Purpose
SM - Standard Missile

SPY - Surface Ship Radar Surveillance
TPY - Transportable Radar Surveillance
UEWR - Upgraded Early Warning Radar

Missile Defense System (MDS)

The Ground-based Midcourse Defense (GMD) weapon system has demonstrated the capability to defend the U.S. homeland from a small number of ballistic missile threats with ranges greater than 3,000 kilometers and employing simple countermeasures when supported by the full architecture of Missile Defense System (MDS) sensors. The Regional/Theater MDS has demonstrated the capability to defend the U.S. Indo-Pacific Command (USINDOPACOM), U.S. European Command (USEUCOM), and U.S. Central Command (USCENTCOM) areas of responsibility against a small number of medium-range ballistic missile (MRBM) or intermediate-range ballistic missile (IRBM) threats with ranges less than 4,000 kilometers, and against representative raids of short-range ballistic missile (SRBM) threats. DOT&E assesses that the top five challenges for the MDS remain the same as last year:

1. The need for realistic and emerging threat representations in flight and ground testing,
2. The need for an adequate, accredited federation of modeling and simulation (M&S) with well understood and documented limitations to assess MDS effectiveness,
3. Cyber-attack against the MDS,
4. Interoperability and maturation of engagement coordination, and
5. The need for test range infrastructure and instrumentation upgrades.

In FY24, the Missile Defense Agency (MDA) flight tested four significant new MDS capabilities:

- Increased battlespace for the GMD weapon system using the upgraded selectable 2/3-stage interceptor.
- Aegis Ballistic Missile Defense (BMD) ability to conduct an integrated air and missile defense engagement against a raid of two SRBMs with Standard Missile-3 (SM-3) Block IA guided missiles, while concurrently engaging two cruise missile targets with SM-2 Block IIIA guided missiles.
- Aegis BMD ability to track, discriminate, engage, and intercept a MRBM target with countermeasures using an SM-3 Block IIA guided missile.
- Aegis BMD ability to detect, track, engage, and intercept an advanced MRBM target using its Sea-Based Terminal Increment 3 capability with SM-6 Dual II guided missiles with software upgrade.

DOT&E will provide additional information and recommendations in the classified DOT&E FY24 Assessment Report of the MDS to be published in February 2025.

SYSTEM DESCRIPTION

The MDS is a geographically distributed system of systems that relies on element interoperability and warfighter integration for combat capability and efficient use of guided missile/interceptor inventory. As shown in Table 1, the MDS consists of six weapon systems, a sensor architecture (i.e., terrestrial, maritime, and global sensors), and a command-and-control element.

Table 1. Elements of MDA's Missile Defense System

Type	U.S. Homeland Defense	Global Regional/Theater Defense	Hypersonic Defense
Weapon Systems	**GMD[a]:** Defends the U.S. homeland against IRBM/ICBM attacks using GBIs to defeat threat missiles during the midcourse segment of flight. The MDA is developing a Next Generation Interceptor to augment the current GBI fleet.	**Aegis BMD[a]:** Both sea-and land-based variants defend U.S. deployed forces and allies from SRBM, MRBM, and IRBM threats. Aegis BMD uses the SM-3 family of guided missiles against exo-atmospheric ballistic missile threats alongside SM-6 guided missiles that Aegis SBT (Inc 2 and Inc 3) uses for endo-atmospheric engagements. Aegis BMD can provide or accept target cues via C2BMC. **THAAD[a]:** Defends U.S. deployed forces and allies from SRBM, MRBM, and IRBM threats using guided interceptors in both the exo- and endo-atmosphere. For extended engagements, THAAD can provide or accept target cues via C2BMC. THAAD complements the upper-tier Aegis BMD and the lower-tier PAC-3 weapon systems. **Patriot[b]:** Defends U.S. deployed forces and allies from SRBM and MRBM threats and aircraft attack and defeats enemy air assets. It is a mobile air and missile defense system employing a mix of PAC-3 hit-to-kill interceptors and PAC-2 blast fragmentation warhead interceptors. Patriot can accept or provide target cues via C2BMC.	**Aegis SBT (Inc 3)[a]:** Provides critical asset protection at sea and for joint forces ashore against ballistic, maneuverable, and hypersonic glide threats in the terminal phase. **GPI[a]:** Will provide an additional layer of hypersonic defense augmenting Aegis SBT (Inc 3) to increase depth of fire against hypersonic threats. The program is currently competitively developing two prototype interceptors.
Terrestrial and Maritime Sensors	**Cobra Dane Radar[d]:** L-band fixed site phased array radar. **UEWRs[d]:** Ultrahigh frequency fixed site phased array radars. **SBX[a]:** X-band mobile phased array radar located aboard a self-propelled, ocean-going platform. **LRDR[a,d,e]:** S-band two-face fixed site phased array radar.	**AN/SPY-1 Radar[c]:** S-band four-face radar providing Aegis long range surveillance and track functions in addition to guided missile engagement support. **AN/SPY-6(V)1 Radar[c]:** S-band four-face radar being installed on new construction Aegis DDG 51 Flight III destroyers. It will extend Aegis threat detection ranges and provide simultaneous ballistic missile and air defense support. **AN/TPY-2 (FBM) Radar[a]:** X-band single-face transportable phased array radar that also supports U.S. homeland defense. **LTAMDS[b]:** C-band three-face multi-function, multi-mission radar interfacing with IBCS and supporting interoperability with PAC-3.	Leverages U.S. homeland defense, global regional/theater defense, and global sensors.
Global Sensors	**SBIRS[d]:** Satellite constellation of infrared sensors. **BOA[a]:** Element that combines OPIR observations to provide missile event and track reports to C2BMC. **SKA[a]:** Network of space sensors providing interceptor hit assessments. **HBTSS[a]:** Network of space sensors to detect and track hypersonic and limited ballistic missile threats and provide fire-control quality data to MDS sensors and weapon systems. MDA launched prototypes in 2QFY24.		
Command and Control	**C2BMC[a]:** Integrating element within the MDS, providing deliberate and dynamic planning, situational awareness, sensor track management, engagement support and monitoring, data exchange between elements, and network management. C2BMC also directs sensor tasking for the LRDR, AN/TPY-2 (FBM) radars, and provides cueing support to BOA.		

Notes:
[a] Under MDA development/sustainment. [b] Under Army development/sustainment. [c] Under Navy development/sustainment. [d] Under Space Force development/sustainment. [e] Under Air Force development/sustainment.

Acronyms: AN/SPY – Army Navy/Surface Ship Radar Surveillance; AN/TPY – Army Navy/Transportable Radar Surveillance; BMD – Ballistic Missile Defense; BMDS – Ballistic Missile Defense System; BOA – BMDS Overhead Persistent Infrared Architecture; C2BMC – Command and Control, Battle Management, and Communications; FBM – Forward-Based Mode; GMD – Ground-based Midcourse Defense; GBI – Ground-Based Interceptors; GPI – Glide Phase Interceptor; HBTSS – Hypersonic and Ballistic Tracking Space Sensor; IAMD – Integrated Air and Missile Defense; IBCS – IAMD Battle Command System; ICBM – Intercontinental Ballistic Missile; Inc – Increment; IRBM – Intermediate-Range Ballistic Missile; LRDR – Long Range Discrimination Radar; LTAMDS – Lower Tier Air and Missile Defense Sensor; MDA – Missile Defense Agency; MDS – Missile Defense System (formerly BMDS); MRBM – Medium-Range Ballistic Missile; OPIR – Overhead Persistent Infrared; PAC – Patriot Advanced Capability; SBIRS – Space-Based Infrared System; SBT – Sea-Based Terminal; SBX – Sea-Based X-band Radar; SKA – Space-Based Kill Assessment; SM – Standard Missile; SRBM – Short-Range Ballistic Missile; THAAD – Terminal High Altitude Area Defense; UEWR – Upgraded Early Warning Radar

MISSION

The Commanders of U.S. Northern Command (USNORTHCOM), USINDOPACOM, USEUCOM, USCENTCOM, and U.S. Space Command (USSPACECOM) employ the assets of the MDS to defend the United States, deployed forces, and allies against missile threats at all ranges and in all phases of flight.

PROGRAM

The MDS is a single Acquisition Category (ACAT) ID program that encompasses five of its six weapon systems (all but Patriot), most of its sensor architecture, and its command-and-control element. In 2002, the SECDEF granted the MDA special acquisition authorities for the MDS. These authorities allowed it to use tailored processes and milestones to deploy new capability, as soon as technologically possible, to defend the United States and its allies against limited ballistic missile attacks. The mission of MDA is to develop and deploy a layered MDS to defend the United States, its deployed forces, allies, and friends from missile attacks in all phases of flight.

The MDA manages the MDS through a single Missile Defense System Acquisition Baseline (MAB). Each Component Program of Record MAB will contain three baselines for Cost, Schedule, and Performance. MDA maintains responsibility for integrating all elements into the MDS, whether or not the MDA developed the element. The MDA publishes a test program plan twice a year in an Integrated Master Test Plan (IMTP) that corresponds to the MDA Program Objective Memorandum submission to the Department and the President's Budget release to Congress DOT&E approves each version of the IMTP, the latest of which is dated September 2024 (version 26.0).

The Army manages the Patriot and Lower Tier Air and Missile Defense Sensor (LTAMDS) programs. Patriot is an ACAT IC program. DOT&E approved the Patriot Post Deployment Build (PDB) 8.1 TEMP in FY20. The LTAMDS program is a Middle Tier of Acquisition program rapid prototyping effort. The Army expects to designate LTAMDS as an ACAT IC program at its Milestone C decision review, planned for 2QFY25. DOT&E approved the LTAMDS initial TEMP in 2019. The program office submitted a TES, which DOT&E approved in August 2024.

The Navy manages the AN/SPY-1 and AN/SPY-6(V)1 radar programs. The AN/SPY-6(V)1 radar is an ACAT IC program. DOT&E approved its TEMP in September 2022.

The Space Force operates and sustains four sensor systems integrated into the MDS: Cobra Dane, five Upgraded Early Warning Radars (UEWRs), the Space-Based Infrared System (SBIRS) constellation, and the Long Range Discrimination Radar (LRDR). The Air Force completed development and initial operational testing for the first three sensor systems prior to them becoming Space Force assets. LRDR will not complete transition and transfer to the United States Space Force until the end of FY25 with the completion of the FTX-26a operational flight test. LRDR has already started providing Space Domain Awareness (SDA) data to the United States Space Force in FY24.

» MAJOR CONTRACTORS

- The Boeing Company
  - GMD Integration, Test and Readiness: Huntsville, Alabama
- Lockheed Martin Corporation
  - Aegis BMD, AAMDS, Aegis SBT, AN/SPY-1 radar, LRDR, and GPI: Moorestown, New Jersey
  - C2BMC: Huntsville, Alabama and Colorado Springs, Colorado
  - NGI AUR in product development: Huntsville, Alabama
  - SBIRS: Sunnyvale, California
  - THAAD Weapon System, PAC-3 Command and Launch System, and PAC- 3 interceptor variants: Dallas, Texas
  - THAAD interceptors: Troy, Alabama
- Northrop Grumman Corporation
  - GMD Weapon Systems Development and GPI prototype: Huntsville, Alabama
  - GBI Boost Vehicles: Chandler, Arizona

  - BOA: Boulder, Colorado; Colorado Springs, Colorado; and Azusa, California
  - HBTSS through Prototype Demonstration Phase: Redondo Beach, California and Azusa, California
- RTX
  - GMD EKV, SM-3/6 Interceptors, LTAMDS, and GPI: Tucson, Arizona
  - Patriot Ground System and PAC-2 interceptor variants, AN/SPY-6(V)1 radar, AN/TPY-2 radar, SBX radar, and UEWRs: Tewksbury, Massachusetts
  - Cobra Dane Radar: Dulles, Virginia
- L3Harris Technologies
  - HBTSS through Prototype Demonstration Phase: Fort Wayne, Indiana
- Johns Hopkins University, Applied Physics Laboratory
  - Space-Based Kill Assessment

TEST ADEQUACY

The MDA IMTP established and documents the test requirements, configurations, resources, test objectives, and target solutions for testing Missile Defense System Phased Implementation Plan Increments with specific focus on collecting the data needed for capability assessment and declaration, as well as the verification, validation, and accreditation (VV&A) of the MDS M&S. The Army documents their test strategy through the Patriot TEMP, and the LTAMDS TES, approved by DOT&E in September 2022 and August 2024, respectively. The MDA conducted testing in accordance with the DOT&E-approved IMTP, although some events experienced technical and programmatic delays. Table 2 outlines the 33 flight, ground, high-fidelity M&S, and cyber survivability test events that the MDA, or Army performed or participated in during FY24. For each test event in Table 2, the footnotes indicate whether DOT&E approved the test plan and whether DOT&E observed the event.

Table 2. FY24 Testing

Date	Test	Mission Area	Description
June 2022 – October 2023	Patriot PDB-8.1 LUT[a,d]	Regional/Theater Defense	The Army conducted this OT to assess the effectiveness, suitability, and survivability of the Patriot PDB-8.1 system through flight testing, accredited HWIL scenarios, and cyber survivability testing (CVPA and AA).
October 2023	Air-Launched Rapid Response Weapon Test Flight-3[c,e]	Hypersonic Defense	The MDA participated in this Air Force event to collect hypersonic missile phenomenology and tracking data to inform future capability development.
October 2023	FTM-48[a,d]	Regional/Theater Defense	The Navy and the MDA demonstrated an Aegis BMD IAMD capability to engage a raid of two SRBMs with two SM-3 Block IA guided missiles, while concurrently engaging a raid of two subsonic anti-ship cruise missile drones with four SM-2 Block IIIA guided missiles. This was the first Aegis BMD IAMD flight mission with raids of both BMD and AAW targets, and the largest IAMD test event in the USINDOPACOM AOR to date.
October 2023 – May 2024	UEWR 22-1 Upgrade[a,e]	Homeland Defense	STARCOM conducted OT on each of the five UEWRs to evaluate the operational effectiveness, suitability, and survivability of those systems after the 22-1 upgrade.
November 2023	Glory Trip 248[c,e]	Homeland Defense	The MDA participated in this Air Force Global Strike Command event to collect data, exercise MDS communication links, and perform future capability assessments, although the flight had anomalies.

Table 2. FY24 Testing, continued

Date	Test	Mission Area	Description
November 2023	Tactical Boost Glide-4[c,e]	Hypersonic Defense	The MDA participated in this DARPA/Air Force event to collect hypersonic missile phenomenology and tracking data to inform future capability development.
November 2023	High Operational Tempo for Hypersonics Campaign-3[c,e]	Hypersonic Defense	The MDA participated in this joint Service flight test event, collecting data on new technologies in hypersonic environments.
November 2023	LTAMDS IFTC 23 OA[d]	Regional/Theater Defense	This Army-conducted OA consisted entirely of a three-day HWIL air battle using unaccredited M&S in the primary sector of LTAMDS. The lack of M&S accreditation was not in accordance with the DOT&E-approved test plan and created uncertainty that the results represented reality. Thus DOT&E determined the OA was not adequate to operationally assess the system performance.
November 2023	LTAMDS DT Missile Flight Test – Air Breathing Target[c,d]	Regional/Theater Defense	The Army demonstrated the capability of a unit equipped with LTAMDS to detect, track, engage, intercept, and kill a subscale aircraft target with one PAC-3 missile.
December 2023	LTAMDS DT Missile Flight Test – Patriot-as-a-Target[c,e]	Regional/Theater Defense	The Army demonstrated the capability of a unit equipped with LTAMDS to detect, track, engage, intercept, and kill a close-range ballistic missile target with two PAC-3 missiles.
December 2023	FTG-12[a,d]	Homeland Defense	The MDA and MDS OTA conducted a DT/OT flight test that demonstrated increased battlespace for the GMD weapon system via the upgraded selectable 2/3-stage interceptor.
February 2024	FTX-23[c,d]	Regional/Theater Defense	The MDA and OPTEVFOR conducted a DT/OT that demonstrated an Aegis BMD capability to detect, track, discriminate, engage, and intercept an MRBM target with countermeasures in the midcourse phase of flight using an SM-3 Block IIA guided missile.
February 2024	System Integration and Checkout-09-4 (USEUCOM/ USCENTCOM)[c,e]	Regional/Theater Defense	The MDA and the MDS OTA conducted this DT/OT limited architecture distributed event using operational assets and focused on the verification of operational communication and message flows of regional/theater capabilities.
March 2024	Cyber Test-09[a,d]	Regional/Theater Defense	The MDA conducted CVPA and AA cyber testing on the C2BMC Spiral 8.2-5.1 as configured for USEUCOM defense to assess cyber survivability.
March 2024	Air-Launched Rapid Response Weapon Test Flight-4[c,e]	Hypersonic Defense	The MDA participated in this Air Force event to collect hypersonic missile phenomenology and tracking data to inform future capability development.
March 2024	FTM-32[a,d]	Regional/Theater Defense	The MDA and OPTEVFOR conducted a DT/OT flight test demonstrating Aegis SBT Increment 3 capability to detect, track, engage, and intercept an advanced MRBM target in the terminal phase of flight using SM-6 Dual II guided missiles with software upgrade.
March 2024	LTAMDS DT Missile Flight Test – Long-Range Cruise Missile[c,d]	Regional/Theater Defense	The Army demonstrated the capability of a unit equipped with LTAMDS to detect, track, engage, intercept, and kill a long-range cruise missile target with one PAC-3 missile.

Table 2. FY24 Testing, continued

Date	Test	Mission Area	Description
March 2024	UEWR Cape Cod CVPA[a,d]	Homeland Defense	STARCOM conducted a CVPA on the Cape Cod UEWR to assess its cyber survivability from insider and nearsider threat postures.
March – May 2024	Patriot Communication Obsolescence Upgrade/Digital Exciter Radar Set Operational Demonstration[a,d]	Regional/Theater Defense	The Army conducted this OT to assess the effectiveness, suitability, and survivability of the Patriot Communication Obsolescence Upgrade and Digital Exciter Radar Set system with accredited HWIL scenarios and cyber survivability testing (CVPA and AA).
April – May 2024	SM-3 Block IIA M&S OT Runs for Record, Phase 2B[a,d]	Regional/Theater Defense	The MDA executed and delivered a set of high-fidelity M&S OT runs for record to assess Aegis BMD remote and organic engagement performance against raids of select threats in scenarios relevant to the USINDOPACOM AOR.
April – June 2024	GTI-08b (USNORTHCOM/ USINDOPACOM)[c,e]	Homeland Defense and Regional/Theater Defense	The MDA and the MDS OTA conducted this DT/OT using HWIL laboratory test assets supporting MDS-level capability assessments in USNORTHCOM/USINDOPACOM geographic regions and examining new functions of Aegis BMD and AN/TPY-2 (FBM).
May 2024	Desert Lion[c,e]	International Partner Exercise	The MDA participated in this exercise to test the MDS capability to acquire & collect data on a high velocity, low altitude target for development of future capabilities against similar threats, and to further continued cooperation & partnership with the Australian Defense Force in missile defense development.
June 2024	Joint Flight Campaign Stool Launch[c,e]	Hypersonic Defense	The MDA participated in this Army/Navy event to collect hypersonic missile phenomenology and tracking data to inform future capability development.
June 2024	Glory Trip 250[c,e]	Homeland Defense	The MDA participated in this Air Force Global Strike Command event to collect data, exercise MDS communication links, and perform future capability assessments.
June 2024	Hypersonic Test Bed-1[c,e]	Hypersonic Defense	The NSWC and MDA conducted this experiment to collect data on the hypersonic environment. The rocket-launched hypersonic vehicle was observed by the HBTSS space sensors.
June 2024	Mk21a-2[c,e]	Homeland Defense	The MDA participated in this Air Force launch of an Mk21a reentry vehicle aboard a Minotaur rocket to collect data, exercise MDS communication links, and perform future capability assessments.
July 2024	GMD HWIL Cyber Lab Event[c,e]	Homeland Defense	The MDA conducted a developmental cyber survivability evaluation of the GMD 8B software configuration in an HWIL environment.
July – December 2024	LTAMDS IFTC 24 OA[a,d]	Regional/Theater Defense	The Army conducted this OT to assess the effectiveness, suitability, and survivability of a unit equipped with LTAMDS through flight test, conditionally accredited HWIL scenarios and cyber survivability testing (CVPA and AA).

Table 2. FY24 Testing, continued

Date	Test	Mission Area	Description
July – August 2024	Live Radiate-08b[c,e]	Space Domain Awareness	The MDA and MDS OTA conducted this DT/OT event to assess MDS tasking (C2BMC) and sensor capability (LRDR and AN/TYPY-2 (FBM) in support of the USSPACECOM space domain awareness mission while maintaining missile defense surveillance.
August 2024	C2BMC HWIL Cyber Lab Event[c,e]	Homeland Defense	The MDA conducted a developmental cyber survivability evaluation of the C2BMC Spiral 8.2-5.1 software configuration in support of NORTHCOM/INDOPACOM in an HWIL environment.
August 2024	AN/TPY-2 HWIL Cyber Lab Event[c,e]	Homeland Defense	The MDA conducted a developmental cyber survivability evaluation of the AN/TPY-2 (FBM) CX 5.0 software configuration in an HWIL environment.
August 2024	Pacific Dragon-24[c,e]	Regional/Theater Defense	The MDA participated in this five-event multilateral warfighter exercise. U.S. and allied naval vessels conducted live and simulated intercepts against SRBM targets with SM-3 Block IA or SM-6 Dual I guided missiles. The exercise demonstrated interoperability between U.S. and allied assets.
September 2024	LRDR HWIL Cyber Lab Event[c,e]	Homeland Defense	The MDA conducted a developmental cyber survivability evaluation of the LRDR 1.0.2 software configuration in an HWIL environment.

Notes:
[a] Testing performed per DOT&E-approved test plan. [b] Test plan not approved by DOT&E. [c] Test plan not required by DOT&E. [d] Test observed by DOT&E. [e] Test not observed by DOT&E.

Acronyms: AA – Adversarial Assessment; AAW – Anti-Air Warfare; AN/TPY - Army Navy/Transportable Radar Surveillance; AOR – Area of Responsibility; AUR – All-Up Round; BD+ – Black Dagger Plus; BMD – Ballistic Missile Defense; C2BMC – Command and Control, Battle Management, and Communications; CVPA – Cooperative Vulnerability and Penetration Assessment; DARPA – Defense Advanced Research Project Agency; DT – Developmental Test; FBM – Forward-Based Mode; FTG – Flight Test GMD Weapon System; FTM – Flight Test Aegis Weapon System; FTX – Flight Test Other; FY – Fiscal Year; GMD – Ground-based Midcourse Defense; HBTSS – Hypersonic and Ballistic Tracking Space Sensor; HWIL – Hardware-in-the-Loop; IAMD – Integrated Air and Missile Defense; IFTC – Integrated Fires Test Campaign; LRDR – Long-Range Discrimination Radar; LTAMDS – Lower Tier Air and Missile Defense Sensor; LUT – Limited User Test; M&S – Modeling and Simulation; MDA – Missile Defense Agency; MDS – Missile Defense System; MFT – Missile Flight Test; MRBM – Medium-Range Ballistic Missile; MSE – Missile Segment Enhancement; NSWC – Naval Surface Warfare Center; OA – Operational Assessment; OPTEVFOR – Operational Test Force; OT – Operational Test; OTA – Operational Test Agency; PAC – Patriot Advanced Capability; PDB – Post Deployment Build; SBT – Sea-Based Terminal; SM – Standard Missile; SRBM – Short-Range Ballistic Missile; STARCOM – Space Training and Readiness Command; UEWR – Upgraded Early Warning Radar; USCENTCOM – U.S. Central Command; USEUCOM – U.S. European Command; USINDOPACOM – U.S. Indo-Pacific Command; USNORTHCOM – U.S. Northern Command, USSPACECOM – U.S. Space Command

As previously reported, the need for additional threat representations, independently accredited M&S, and system survivability data in a cyber-contested environment presents significant challenges for completing a comprehensive assessment of the MDS. Specifically:

- The current MDS M&S is not adequate to conduct operational assessments. Realistic and up-to-date representations of threat missile scenes are critical to the assessment of MDS performance. As DOT&E has noted since FY21, the rate of adversary threat development is currently faster than the pace of flight test target and ground test high-fidelity M&S threat model development. The MDA, in conjunction with the MDS Operational Test Agency (OTA), recently chartered a Lethality Model Working Group to support sharing and VV&A of theater threat models among the elements. The MDA has made

advancements to their threat modeling process, but models can still take several years to develop.

- Independent accreditation of M&S used in ground tests and high-fidelity analyses is needed to ensure adequate representation of current threat missile capabilities, electronic attacks, countermeasures, vulnerabilities, post-intercept debris, and realistic raid sizes. DOT&E has emphasized this need in previous annual reports. The rate at which the MDA's models have been independently accredited has increased, but significant gaps remain. While over 90 percent of element and sensor models are accredited in ground tests, critical M&S components like newer threat models and post-intercept debris models remain unaccredited. Validation of post-intercept debris models requires flight testing with targets that include threat-representative payloads. As threat and system model capabilities become more complex, the MDA has struggled to maintain a real-time test architecture that can handle this complexity. This issue will become critical as more complex capabilities are added to the MDS, such as the Next Generation Interceptor (NGI) and the Glide Phase Interceptor (GPI), and to support Guam Defense scenarios involving numerous simultaneous air and missile threats. As a complement to the real-time testing, the MDA had been developing the End-to-end Digital Integrated System-level Simulation, a high-fidelity digital modeling architecture needed to assess effectiveness of the MDS. In FY24, the MDA removed funding from the effort. The operational effectiveness of the MDS cannot be fully assessed without such a tool.
- The MDS has an extensive cyber-attack surface, which to date, has not been rigorously tested in operationally realistic settings at the MDS-level. MDS-level cyber survivability assessments with multiple elements, warfighter participation, and federated M&S accredited for performance, are needed to identify the full mission effects of cyber-attacks. To date, the MDA has struggled to maintain the scope of such MDS-level tests as specified in the IMTP, in part because of lack of MDS operational element availability, due to real-world events. The MDA, in coordination with the Services and MDS OTA, should routinely conduct rigorous, operationally realistic cyber testing of the MDS to assess and improve the cyber survivability of critical missile defense capabilities.
- While the MDA strives for operational realism, however, flight and ground test programs and high-fidelity M&S analyses at both the MDS system- and element-level have been limited in the variety of realistic threat countermeasures, electronic attack, post-intercept debris scenes, raid sizes, and multi-element engagement scenarios. As reported in the DOT&E FY22 and FY23 Annual Reports, the MDA often designs flight tests to demonstrate a specific new capability, but not for operational realism. Operationally realistic intercept flight tests are necessary to provide: (1) needed referent data to support VV&A of models used in high-fidelity M&S and ground testing; (2) realistic data on multi-element interactions; and (3) data in multi-domain operations.
- The Army, Navy, and MDA, in coordination with DOT&E, are working to develop a test strategy for the Guam Defense System, which is intended to provide persistent, 360-degree, layered, and integrated air and missile defense capability for the defense of Guam. The proposed architecture is made of both new and existing systems in close proximity and with overlapping areas of regard, with all components working together to defend against cruise, ballistic, and hypersonic threats. This architecture presents a significant integration and test planning challenge. DOT&E assesses that the current test strategy needs significant further development to achieve adequacy. An Agile test program that fully explores interoperability and engagement planning through a coordinated strategy of mutually supporting ground testing, digital M&S, tracking exercises, and intercept flight testing is warranted. Comprehensive suitability and cyber tests are also needed.
- The MDA is also facing a significant test resource shortfall, with two major test support ships, the Pacific Collector and the Pacific Tracker, nearing end-of-life. The MDA has been considering courses of action, but there is a funding gap. NGI and future target characteristics will require shipboard radar upgrades for

these assets. These ships also support flight testing of other major DoD programs.

PERFORMANCE

» U.S. HOMELAND MISSILE DEFENSE

With the support of the full architecture of MDS sensors, the GMD weapon system has demonstrated the capability to defend the U.S. homeland from a small number of ballistic missile threats employing simple countermeasures and with ranges greater than 3,000 kilometers. In FY24, the MDA demonstrated the increased engagement battlespace of GMD with an intercept flight test using the selectable 2/3-stage interceptor. The AN/TPY-2 Forward-Based Mode (FBM) and Sea-Based X-band (SBX) radars supported GMD during the test. In FY24, the MDA continued hypervelocity impact testing to support development of M&S for NGI lethality assessments.

» REGIONAL/THEATER MISSILE DEFENSE

The regional/theater MDS has demonstrated a capability to defend the USINDOPACOM, USEUCOM, and USCENTCOM areas of responsibility from a small number of MRBM or IRBM threats with ranges less than 4,000 kilometers, and from representative raids of SRBM threats.

Aegis BMD has demonstrated the capability to intercept non-separating, simple-separating, and complex-separating ballistic missiles in the midcourse phase of flight with SM-3 guided missiles, although flight testing and M&S have not addressed all expected threat types, threat features, and raid sizes. In FY24, Aegis BMD conducted its first-ever integrated air and missile defense engagement with a raid of ballistic missiles and a concurrent raid of cruise missiles, and its most stressing engagement against a ballistic missile target with countermeasures. In April 2024, for the first time in a live combat environment, two Aegis BMD destroyers successfully engaged Iranian ballistic missile threats targeting Israel with SM-3 Block IB guided missiles. In FY24 and prior years, Aegis BMD has demonstrated a capability to intercept select ballistic missiles in the terminal phase of flight with its Sea-Based Terminal capability with SM-6 guided missiles.

All fielded Aegis BMD variants have demonstrated sufficient reliability, with operational availabilities that exceed the specification. SM-3 Block IB Threat Upgrade and SM-3 Block IIA guided missiles are reliable, as they meet their threshold reliability metrics, but not with statistical confidence because of the relatively small number of live firings to date. The full production acquisition decision memorandums for the SM-3 Block IB and SM-3 Block IIA require periodic flight testing of these missiles throughout the life of the program, which improves reliability data counts over time. SM-6 missiles have been reliable in anti-air warfare and BMD flight testing.

The Terminal High Altitude Area Defense (THAAD) system has demonstrated the capability to intercept and destroy SRBMs, MRBMs, and IRBMs inside or outside the earth's atmosphere during the terminal phase of flight. However, flight testing and M&S still need to address more complex engagement conditions and realistic raid scenarios. In FY24, the MDA canceled Flight Test THAAD Weapon System-25 (FTT-25) due to the operational status of equipment and unit unavailability resulting from real-world events. The FTT-25 flight test requirements have been reallocated to FTT-26, a FY27 scheduled DT/OT event. The last flight test to use a THAAD interceptor was in FY19, and a future test will not occur until FY27, generating a large flight test gap for the THAAD interceptor. Despite this, the MDA continues to develop and deploy updates to the THAAD software and hardware for the radar, and software updates to THAAD Fire Control and Communications. The MDA and the Army continue to address THAAD training and component reliability shortfalls.

Patriot has demonstrated the capability to provide point defense against missile and aircraft attacks on deployed forces and critical assets and to defeat enemy aircraft. The Patriot PDB-8.1 Limited User Test (LUT) assessed how Patriot effectiveness, suitability, and survivability have changed since the last Patriot operational test that concluded in April 2019. DOT&E published the results of the PDB-8.1

LUT in a separate classified report in 1QFY24. Patriot PDB-8.1 training and human system integration improved over PDB-8, but shortfalls remain in reliability and survivability. As reported in the DOT&E FY23 Annual Report, the Patriot M&S representations for ground tests used the Battalion Simulation under development by the Army, but the Army has not yet provided sufficient verification and validation (V&V) evidence to accredit the Battalion Simulation for performance assessments. The Army should provide sufficient V&V evidence for the Battalion Simulation or work with MDA to determine a way ahead for a new Patriot representation to integrate and use to support regional/theater performance assessments during MDS ground tests.

AN/TPY-2 (FBM) and AN/SPY-1 radars contribute to regional/theater defense and monitoring. In the future, AN/SPY-6(V)1 radars on Aegis Flight III destroyers will also contribute to those missions. AN/TPY-2 (FBM) detected and tracked an IRBM target in an FY24 GMD flight test. In FY24, AN/SPY-1 demonstrated the capability to detect, track, and discriminate an MRBM with countermeasures during a live intercept flight test, and the capability to detect and track an IRBM during a GMD flight test. The AN/SPY-6(V)1 radar prototype at the Pacific Missile Range Facility, Hawaii, continues to track all classes of ballistic missiles, as available, during MDA flight tests. The first Aegis Flight III destroyer with Aegis Baseline 10, USS *Jack H. Lucas* (DDG 125), detected and tracked two MRBM targets in FY24 with its AN/SPY-6(V)1 radar, though corrective action is needed to address observed anomalies. These anomalies created shortfalls in the data needed to validate the high-fidelity M&S for Aegis Baseline 10 operational test runs for record.

The Army conducted an LTAMDS operational assessment as part of the Integrated Fires Test Campaign 23 (IFTC 23). DOT&E determined that IFTC 23 was inadequate to support an assessment of operational effectiveness for the LTAMDS system, due to immature and unaccredited LTAMDS M&S tools. These M&S challenges persist in IFTC 24. The Army should focus on efficiently using developmental testing to support M&S tool development, verification, validation, and accreditation. See the IFTC article in this Annual Report for additional details.

» HYPERSONIC MISSILE DEFENSE

The MDA collected hypersonic test data throughout FY24 to inform future sensors, sensor detection and tracking algorithms, and M&S validation. The MDA also conducted ground hypervelocity impact, thermal, and aerodynamic testing to support the development of the M&S architecture for hypersonic missile defense.

» COMMAND AND CONTROL AND SPACE SENSORS

Almost every FY24 test conducted by the MDA included space sensors acquiring, tracking, and reporting on observed objects. The prototype Hypersonic and Ballistic Tracking Space Sensor (HBTSS) performed its first data collection on a hypersonic target. Command and Control, Battle Management, and Communications (C2BMC) globally and regionally integrates and synchronizes autonomous sensors, weapon systems, and operations. C2BMC is also a part of all system ground and flight tests, which verify and exercise current and future MDS capabilities. In FY24, C2BMC and the BMDS Overhead Persistent Infrared Architecture (BOA) continued to support real-world situational awareness in USEUCOM and USCENTCOM. In a live-radiate event in FY24, C2BMC communicated with Space Command and Control for space domain awareness, tasking LRDR and AN/TPY-2 (FBM) and receiving reports back from the radars on resident space objects.

» SUMMARY

DOT&E will provide additional information in the classified DOT&E FY24 Assessment Report of the MDS due out in February 2025.

RECOMMENDATIONS

The MDA should:

1. Increase the rate of U.S. homeland defense, regional/theater target, and threat model development to keep pace with emerging

real-world threats, as recommended in the FY23 Annual Report.

2. To ensure adequate operational assessments, prioritize development and independent accreditation of M&S used in ground tests and high-fidelity analyses and ensure M&S accurately represent current threat capabilities, electronic attack, countermeasures, vulnerability, post-intercept debris, and realistic raid sizes.
3. Plan flight tests to support M&S VV&A to allow quantitative assessments of both current MDS capability, as well as more complex future capabilities that will require such a capability, like the Guam Defense System, NGI, and GPI.
4. Continue investments in ground test architecture improvements to accommodate more complex threat and system model features.
5. Ensure that relevant intercept flight testing with operationally representative targets is conducted prior to any planned M&S operational testing runs for record, to provide referent data to support VV&A of the models representing post intercept debris to enable adequate operational assessments.
6. Conduct high-fidelity M&S runs for record with independently accredited M&S to assess individual weapon system and MDS-level operational effectiveness against emerging threats.
7. Prioritize working with the DoD to find a solution to extend or replace the Pacific Tracker and Pacific Collector ships and install new shipboard radars before NGI testing begins.
8. Ensure comprehensive cyber test and evaluation plans are created and developmental and operational cyber testing is completed, prior to capability delivery of MDS element and interceptor builds to the warfighter.
9. Conduct routine operational cyber survivability assessments with multiple elements, warfighter participation, and federated M&S accredited for performance.
10. Coordinate with the Army and Navy to ensure the test strategy for the Guam Defense System incorporates multi-element interoperability and coordination into intercept flight testing, tracking exercises, ground testing, and digital M&S. Additionally, ensure comprehensive system-level suitability and cyber testing is planned, as recommended in the FY23 Annual Report.

The Army should:

1. Provide sufficient V&V evidence for the Battalion Simulation or work with MDA to identify a new Patriot representation to integrate and use to support regional/theater performance assessments during MDS ground tests.
2. Coordinate with MDA to ensure the test strategy for the Guam Defense System incorporates multi-element interoperability and coordination into intercept flight testing, tracking exercises, ground testing, and digital M&S. Additionally, ensure comprehensive system-level suitability and cyber testing is planned, as recommended in the FY23 Annual Report.
3. Ensure that the M&S tools required for LTAMDS performance evaluations are validated, verified, and accredited prior to test execution.

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