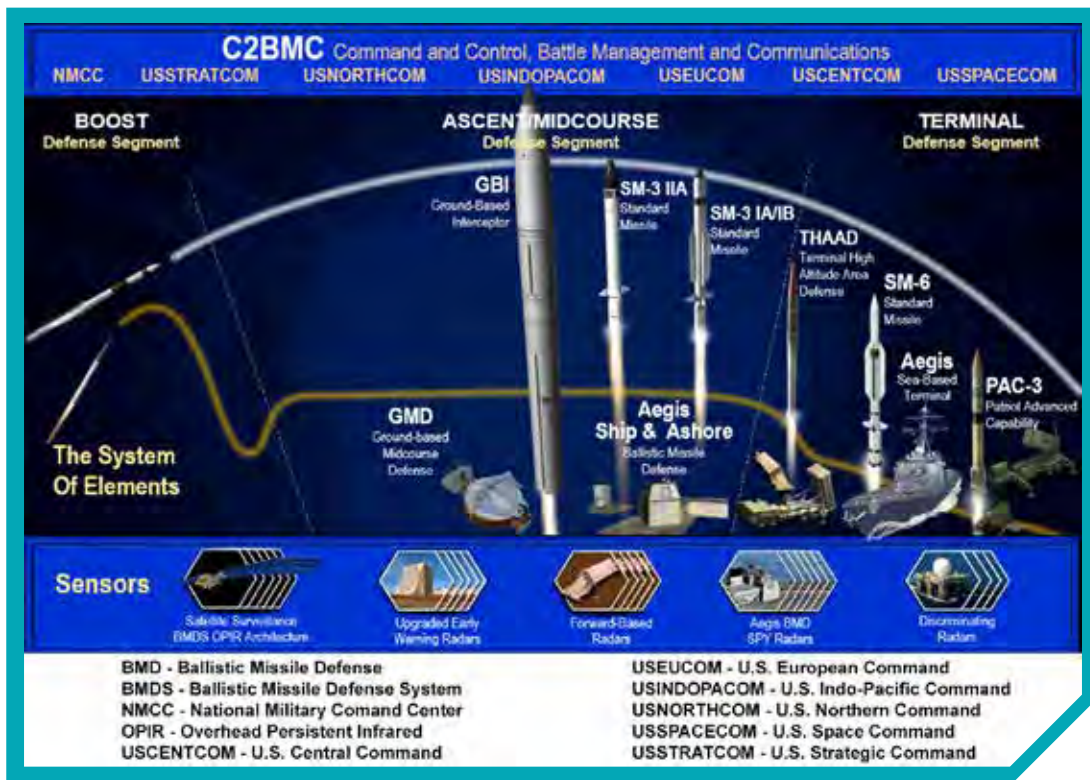




Missile Defense System

|| The Missile Defense System (MDS) has demonstrated a measured capability to defend the United States, deployed forces, and allies from a rogue nation's missile attack.



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. Similarly, 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 from a small number of medium- or intermediate-range ballistic missile threats with ranges less than 4,000 kilometers, and from representative raids of short-range ballistic missile (SRBM) threats. In FY21, the Missile Defense Agency (MDA) fielded five significant capabilities to the MDS. Additional information and recommendations from each section of this article may be found in the Controlled Unclassified Information edition of this article and the classified DOT&E FY21 Assessment of the MDS report to be published in February 2022.

System Description

The MDA's 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. The commanders of USNORTHCOM, USINDOPACOM, USEUCOM, and USCENTCOM employ the MDS elements, as available to them, to defend the United States, deployed forces, and allies against ballistic and hypersonic missile threats of all ranges. The MDS consists of six weapon systems, a sensor architecture (terrestrial, maritime, and global sensors), and a command and control element as shown in Table 1.

Table 1. Elements of MDA’s Missile Defense System

Type	Homeland Defense	Global Regional / Theater Defense	Hypersonic Defense
Weapon Systems	<p>GMD: Defends the U.S. Homeland against IRBM/ICBM attacks using Ground-Based Interceptors to defeat threat missiles during the midcourse segment of flight. MDA is developing a Next Generation Interceptor to supplement the current Ground-Based Interceptor fleet.</p>	<p>Aegis BMD: 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 are used by the Aegis SBT (Inc 1 and Inc 2 CU) for endo-atmospheric engagements.</p> <p>THAAD: 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 from Aegis BMD or other sensors via C2BMC. THAAD complements the upper-tier Aegis BMD and the lower-tier PAC-3 weapon systems.</p> <p>PAC-3^b: Defends U.S. deployed forces and critical assets from SRBM 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.</p>	<p>Aegis SBT (Inc 3)^a: Aegis SBT provides critical asset protection at sea and for joint forces ashore against ballistic, maneuverable, and hypersonic glide threats in the terminal phase.</p> <p>GPI^a: Provides an additional layer of Hypersonic Defense augmenting Aegis SBT (Inc 3) to increase depth of fire against hypersonic threats. The program is currently in development of prototype interceptors.</p>
Terrestrial and Maritime Sensors	<p>COBRA DANE Upgrade^d: L-band fixed site phased array radar.</p> <p>UEWRs^d: Ultrahigh frequency fixed site phased array radars.</p> <p>SBX: X-band mobile phased array radar (XBR) located aboard a self-propelled, ocean-going platform.</p> <p>LRDR^a: S-band two-face fixed site phased array radar.</p>	<p>AN/SPY-1 Radar: S-band four-face radar providing Aegis long-range surveillance and track functions in addition to guided missile engagement support.</p> <p>AN/SPY-6(V)1 Radar^c: Being developed to replace the AN/SPY-1 radar on Aegis DDG 51 Flight III destroyers, this S-band four-face radar will extend Aegis threat detection ranges and provide simultaneous ballistic missile and air defense support.</p> <p>AN/TPY-2 (FBM) Radar: X-band single-face transportable phased array radar.</p> <p>LTAMDS^b: C-band three-face multi-function, multi-mission radar interfacing with IBCS and supporting interoperability with PAC-3.</p>	Leverages Homeland Defense, Regional/Theater Defense, and Global sensors.
Global Sensors	<p>SBIRS^d: Satellite constellation of infrared sensors.</p> <p>BOA: Element that combines OPIR observations to provide missile event and track reports to C2BMC.</p> <p>SKA^a: Network of space sensors providing interceptor hit assessments.</p> <p>HBTSS^a: Network of space sensors to detect and track both ballistic and hypersonic threats, and provide fire-control quality data to MDS sensors and weapon systems.</p>		
Command and Control	<p>C2BMC: 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 AN/TPY-2 (FBM) radars and BOA systems.</p>		

^a Under MDA development. ^b Under Army development. ^c Under Navy development. ^d Under Space Force sustainment/operations.

BMD – Ballistic Missile Defense; BMDS – Ballistic Missile Defense System; BOA – BMDS Overhead Persistent Infrared Architecture; C2BMC – Command and Control, Battle Management, and Communications; CU – Capability Upgrade; FBM – Forward-Based Mode; GMD – Ground-based Midcourse Defense; 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; SKA – Space-based Kill Assessment; SM – Standard Missile; SRBM – Short-Range Ballistic Missile; THAAD – Terminal High Altitude Area Defense; UEWR – Upgraded Early Warning Radar; XBR – X-Band Radar

Program

The MDS is a single Acquisition Category ID program that encompasses five of its six weapon systems, most of its sensor architecture, and its command and control element. In 2002, the Secretary of Defense granted the MDA special acquisition authorities for the MDS, which allowed it to use tailored processes and milestones rather than those specified in the DOD 5000 series of acquisition instructions. The MDA manages the MDS through a series of six program baselines (Schedule, Test, Technical, Resource, Contract, and Operational Capacity) and maintains responsibility for integrating all elements into the MDS whether or not the MDA developed the element. The MDA publishes the Test Baseline 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 was dated October 2021.

The Army is managing the PAC-3 and the Lower Tier Air and Missile Defense Sensor (LTAMDS) programs. PAC-3 is an Acquisition Category IC program. DOT&E approved the PAC-3 PDB 8.1 Test and Evaluation Master Plan (TEMP) in FY20.

The LTAMDS is a Middle Tier Rapid Prototyping program expected to be designated an Acquisition Category IC program at its Materiel Development Decision scheduled for FY23. DOT&E approved its initial TEMP in 2019, with an update currently in process.

The Navy is managing the AN/SPY-6(V)1 radar program, an Acquisition Category IC program. Its TEMP is under development, with anticipated DOT&E approval in FY22.

The Space Force sustains and operates three sensor types integrated into the MDS: COBRA DANE Upgrade, five UEWRs, and the SBIRS constellation. The Air Force has completed development and initial operational testing for these sensors.

Major Contractors

Table 2. MDS Major Contractors
The Boeing Company
GMD Integration: Huntsville, Alabama
Lockheed Martin Corporation
Aegis BMD, AAMDS, Aegis SBT, AN/SPY-1 radar, LRDR, and GPI through Phase I: Moorestown, New Jersey C2BMC: Huntsville, Alabama, and Colorado Springs, Colorado NGI AUR through Critical Design Review: 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
GBI Booster Vehicles: Chandler, Arizona GMD GCN, LMS, and GFC: Huntsville, Alabama NGI AUR through Critical Design Review: Chandler, Arizona BOA: Boulder, Colorado; Colorado Springs, Colorado; and Azusa, California HBTSS through Prototype Demonstration Phase: Redondo Beach, California, and Azusa, California

1. The MDA recently updated the system title to the MDS, dropping “Ballistic,” to acknowledge the addition of maneuvering and hypersonic threat missiles to its missile defense charter.

Table 2. MDS Major Contractors

Raytheon Technologies Corporation

GMD EKV, SM-3/6 Interceptors, and LTAMDS: Tucson, Arizona
 PAC-3 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

L3 Harris Technologies

GMD IDT: Melbourne, Florida
 HBTSS through Prototype Demonstration Phase: Fort Wayne, Indiana

Johns Hopkins University, Applied Physics Laboratory

SKA: Laurel, Maryland

AAMDS – Aegis Ashore Missile Defense System; AUR – All-Up Round; BMD – Ballistic Missile Defense; BMDS – Ballistic Missile Defense System; BOA – BMDS Overhead Persistent Infrared Architecture; C2BMC – Command and Control, Battle Management, and Communications; EKV – Exo-atmospheric Kill Vehicle; GCN – GMD Communications Network; GFC – Ground Fire Control; GMD – Ground-based Midcourse Defense; GPI – Glide Phase Interceptor; HBTSS – Hypersonic and Ballistic Tracking Space Sensor; IDT – GMD In-Flight Interceptor Communication System Data Terminals; LMS – Launch Management System; LRDR – Long Range Discrimination Radar; LTAMDS – Lower Tier Air and Missile Defense Sensor; MDS – Missile Defense System (formerly BMDS); NGI – Next Generation Interceptor; PAC – Patriot Advanced Capability; SBIRS – Space-Based Infrared System; SBT – Sea-Based Terminal; SBX – Sea-Based X-band; SKA – Space-based Kill Assessment; SM – Standard Missile; THAAD – Terminal High Altitude Area Defense; UEWR – Upgraded Early Warning Radar

Test Adequacy

The MDA MDS test plan focuses on collecting the flight, ground, and cybersecurity test data needed for contract compliance and operational capability declarations, as well as for the verification, validation, and accreditation of associated M&S. The adequacy assessment of the MDS test plan is based on the: 1) degree of collected data, 2) breadth of tested battlespace, 3) extent of covered threat set, 4) completeness of cybersecurity assessments, and 5) operational realism. The MDA conducted testing in accordance with the DOT&E-approved IMTP as affected by the COVID-19 pandemic. Due to the COVID-19 pandemic, the MDA delayed and modified flight, ground, and cybersecurity test events across the MDS. Table 3 outlines the 17 flight, ground, and cybersecurity test events that the MDA performed in FY21.

Table 3. FY21 Test Events

Date	Test	Mission Area	Description
October 2020	Flight Test Patriot Weapon System-27 Event 1	Global Regional/Theater Defense	The MDA, Army PEO M&S, and Army SMDC exercised the PAC-3 launch-on-remote capability using THAAD AN/TPY-2 (TM) sensor data. This demonstration will support the 2016 NDAA interoperability requirement.
November 2020	Flight Test Aegis Weapon System-44	Homeland Defense	The MDA demonstrated Aegis BMD engage-on-remote capability using a live SM-3 Block IIA guided missile to engage a simple ICBM in a Defense of the Hawaiian Islands scenario. This test fulfilled a 2018 NDAA requirement.

Table 3. FY21 Test Events

Date	Test	Mission Area	Description
December 2020	Tactical Boost Glide-1	Hypersonic Defense	The MDA and DARPA conducted a joint hypersonic missile phenomenology data collection and tracking exercise to inform future capability development.
December 2020	Sea-Based X-Band Radar Cooperative Vulnerability and Penetration Assessment, and Adversarial Assessment	Homeland Defense	The MDA, BMDS OTA, and the Army's DEVCOM DAC and TSMO performed a limited CVPA and AA on the XBR installed on SBX exploring insider and nearsider threat postures.
March 2021	Ground Test Integrated-21 Sprint 2	Homeland Defense and Global Regional/Theater Defense	The MDA conducted this test to examine MDS performance using different AN/TPY-2 (FBM) radar versions with the C2BMC and GMD elements for the BMD of the Homeland and USINDOPACOM AOR missions.
April 2021	At-Sea Demonstration-1	Global Regional/Theater Defense	The MDA conducted an Aegis AN/SPY 1 radar SDA mission providing sensor tracking of resident space objects. This test informed radar performance and C2BMC/Space C2 interfaces for mission tasking.
May 2021	Formidable Shield 2021	Global Regional/Theater Defense	Eight NATO countries and the United States conducted an exercise integrating in-theater Aegis BMD baselines to support a common tactical picture. Four events were executed including exo- and endo-atmospheric simulated and live-fire engagements with information transfer over USEUCOM/NATO operational networks. These events also supported the acquisition program mandate for SM-3 SLEP data collection every two years.
May 2021	Flight Test Aegis Weapon System-31 Event 1	Global Regional/Theater Defense	The MDA executed an endo-atmospheric engagement using two BMD-configured SM-6 Block IA guided missiles against a single MRBM threat. This demonstration will inform Aegis SBT Increment 2 program.
July 2021	Flight Test Aegis Weapon System-33	Global Regional/Theater Defense	The MDA executed an endo-atmospheric engagement using four BMD-configured SM-6 Block IA guided missiles against a raid of two SRBM threats. This operational test will inform Aegis SBT Increment II program.
July 2021	Hypersonic Air-Breathing Weapon Concept-4	Hypersonic Defense	The MDA and DARPA conducted a joint hypersonic missile phenomenology data collection and tracking exercise to inform future capability development.
July 2021	AN/TPY-2 Radar Hardware-in-the-Loop Cooperative Vulnerability and Penetration Assessment	Global Regional/Theater Defense	The MDA, BMDS OTA, and the Army's DEVCOM DAC performed a limited CVPA on the AN/TPY-2 (FBM) radar using a HWIL laboratory representation. Insider and nearsider threat postures were explored.
August 2021	Aegis Weapon System Controlled Test Vehicle-04	Global Regional/Theater Defense	The MDA demonstrated the upgraded SM-3 Block IIA Guidance Electronics Unit against a simulated target to meet its flight performance requirements.

Table 3. FY21 Test Events

Date	Test	Mission Area	Description
August 2021	Ground Test Integrated-21 Sprint 1	Homeland Defense and Global Regional/Theater Defense	The MDA conducted this test to assess THAAD capabilities in USINDOPACOM. The test also provided data to support an assessment of AN/TPY-2 (FBM) radar capabilities in USNORTHCOM and USINDOPACOM scenarios, and an assessment of interoperability between the MDS and SBIRS.
September 2021	Ground-based Midcourse Defense Weapon System Booster Vehicle Test-03	Homeland Defense	The MDA conducted a booster vehicle flyout to exercise 2-stage booster capability and 2-/3-stage selectable fire control software. This test was a component-level demonstration within the GMD element.
September 2021	Terminal High Altitude Area Defense Weapon System Controlled Test Vehicle-01	Global Regional/Theater Defense	The MDA attempted to demonstrate THAAD control of two PAC-3 interceptors against a simulated SRBM threat, but the test failed.
September 2021	At-Sea Demonstration-2	Global Regional/Theater Defense	The MDA conducted an Aegis AN/SPY 1 radar SDA mission providing sensor tracking of resident space objects. This test informed radar performance and C2BMC/Space C2 interfaces for mission tasking.
September 2021	Hypersonic Air-Breathing Weapon Concept-5	Hypersonic Defense	The MDA and DARPA conducted a joint hypersonic missile phenomenology data collection and tracking exercise to inform future capability development.

AA – Adversarial Assessment; AOR – Area of Responsibility; BMD – Ballistic Missile Defense; BMDS – Ballistic Missile Defense System; C2 – Command and Control; C2BMC – Command and Control, Battle Management, and Communications; CVPA – Cooperative Vulnerability and Penetration Assessment; DARPA – Defense Advanced Research Project Agency; DEVCOM DAC – Combat Capabilities Development Command Data and Analysis Center; FBM – Forward-Based Mode; FY – Fiscal Year; GMD – Ground-based Midcourse Defense; HWIL – Hardware-in-the-Loop; ICBM – Intercontinental Ballistic Missile; M&S – Modeling and Simulation; MDA – Missile Defense Agency; MDS – Missile Defense System; MRBM – Medium-Range Ballistic Missile; NATO – North Atlantic Treaty Organization; NDAA – National Defense Authorization Act; OTA – Operational Test Agency; PAC – Patriot Advanced Capability; PEO M&S – Program Executive Office-Missiles and Space; SBIRS – Space-Based Infrared System; SBT – Sea-Based Terminal; SBX – Sea-Based X-Band; SDA – Space Domain Awareness; SLEP – Service Life Extension Program; SM – Standard Missile; SMDC – Space and Missile Defense Command; SRBM – Short-Range Ballistic Missile; THAAD – Terminal High Altitude Area Defense; TM – Terminal Mode; TSMO – Threat Systems Management Office; USEUCOM – U.S. European Command; USINDOPACOM – U.S. Indo-Pacific Command; USNORTHCOM – U.S. Northern Command; XBR – X-Band Radar

Performance

The need for additional realistic and emerging threat representations, independently accredited M&S to creditably assess system effectiveness, and system survivability data in a cyber-contested environment present significant challenges for DOT&E in completing a comprehensive assessment of the MDS:

- Realistic and up-to-date representations of threat scenes are critical to the assessment of MDS performance. The rate of adversary threat development is currently faster than the pace of flight test target and ground test threat model development.
- The MDA and the MDS Operational Test Agency (OTA) continued to make progress in FY21 by increasing the number of OTA-accredited models and mitigating model limitations, but gaps remain.
- The MDS is a large system of systems with a potentially extensive cyberattack surface. While the MDA and the MDS OTA made progress in cybersecurity T&E efforts, there is still no standard approach for implementing cybersecurity and cyber-resiliency.

Ballistic Missile Defense for the Homeland

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.

Ballistic Missile Defense for the Global Regional/Theater

The Regional/Theater MDS has demonstrated capability to defend the USINDOPACOM, USEUCOM, and USCENTCOM areas of responsibility from a small number of medium- or intermediate-range ballistic missile threats with ranges less than 4,000 kilometers, and from representative raids against SRBM threats.

Hypersonic Missile Defense

The MDA collected data throughout FY21 to inform future sensors, sensor detection and tracking algorithms, and M&S validation.

Global Sensors and Command and Control

Almost every test conducted by the MDA included global sensors, as well as sensors unique to Homeland and Regional/Theater Defense to acquire, track, and report on observed objects. C2BMC is a force multiplier that globally and regionally integrates and synchronizes autonomous sensors, weapon systems, and operations to optimize MDS effectiveness. C2BMC is an integral part of all system ground and flight tests, which verify and exercise all current and future MDS capabilities. Additional details will be published in a separate classified C2BMC report in FY22.

Recommendations

The MDA should:

1. Increase the rate of target and threat model development to keep pace with the real-world threats.
2. Conduct the required operational cybersecurity assessments on all MDS elements and implement fixes, specifically:
 - Ensure that cybersecurity principles are included in element design, comprehensive cyber T&E plans are created and included in the IMTP, and developmental and operational cyber testing is completed prior to capability delivery to the warfighter.
 - Consider conducting technical working groups with cyber experts and DOT&E before/after each cybersecurity assessment to identify data gaps, review test requirements to focus future testing, ensure post-test analysis is thorough and well documented, and define what constitutes a cyber-secure system.

The Army should:

1. Continue to develop the PAC-3 Battalion Simulation to address current shortfalls in supporting performance assessments.