Sensors / Command and Control Architecture

Aegis AN/SPY-1 Radar

AN/TPY-2

Cobra Dane

C2BMC

UEWR

SBIRS

Sea-Based X-band Radar

C2BMC - Command and Control, Battle Management and Communications
SBIRS - Space-Based Infrared System
UEWR - Upgraded Early Warning Radars

Executive Summary

- The Missile Defense Agency (MDA) continued to mature the Ballistic Missile Defense System (BMDS) sensors/command and control architecture. The MDA:
  - Used the sensors and/or the command and control architecture in nine tests and supported four additional Air Force intercontinental ballistic missile (ICBM) reliability and sustainment flight tests.
  - Completed the Critical Design Review for the Long-Range Discrimination Radar.
  - Initiated the defense of Hawaii radar program.
  - Completed the Sensor Analysis of Alternatives and presented the findings to the Missile Defense Executive Board.
- The Army Research Laboratory Survivability/Lethality Directorate (ARL/SLAD) conducted a Cooperative Vulnerability and Penetration Assessment (CVPA) of the Command and Control, Battle Management, and Communications (C2BMC) system and the BMDS Overhead Persistent Infrared Architecture (BOA), as well as a limited CVPA (no penetration testing) on the AN/TPY-2 (Forward-Based Mode (FBM)) radar to identify cybersecurity vulnerabilities; verify fixes for some vulnerabilities; and collect data on a new tool intended to improve C2BMC network defense. The MDA has not yet conducted Adversarial Assessments (AAs) on any sensors or command and control assets in the BMDS architecture, which are necessary to support a cybersecurity survivability assessment.
- The MDA and the Army continue working to achieve Full Materiel Release of the AN/TPY-2 (FBM) radar. Of the 33 total materiel release conditions, 9 have been closed and the remaining 24 are expected to be closed in the next 2 years.
- AN/TPY-2 (FBM) radar operator training and Interactive Electronic Technical Manuals (IETMs) continue to be deficient.
- The MDA began ground testing C2BMC Spiral 8.2 (S8.2), which implements a redundant unified client that replaces two independent clients implemented in C2BMC S6.4.

System

- The BMDS sensors are systems that provide real-time ballistic missile threat data to the BMDS. The Services use the data to counter ballistic missile attacks. The Army, Navy, Air Force, and the MDA operate the sensor systems.
  - The COBRA DANE radar is a fixed site, single-face, L-band phased array radar operated by the Air Force and located at Eareckson Air Station (Shemya Island), Alaska.
  - The Upgraded Early Warning Radars (UEWRs) are fixed site, multiple-face, ultrahigh frequency radars, operated by the Air Force and located at Beale AFB, California, and Thule Air Base, Greenland (two radar faces each location).

A third radar is operated by the Royal Air Force (RAF) with Air Force liaisons on site at RAF Fylingdales, United Kingdom (three radar faces). The MDA and Air Force Space Command are also upgrading the Early Warning Radars in Clear Air Force Station, Alaska, and Cape Cod Air Force Station, Massachusetts (projected fielding for both is FY18).

- The Sea-Based X-band (SBX) radar is a mobile, phased array radar operated by the MDA and located aboard a twin-hulled, semi-submersible, self-propelled, ocean-going platform.
- The AN/TPY-2 (FBM) radar is a transportable, single-face, X-band phased array radar commanded and tasked by the C2BMC, and located at sites in Japan, Israel, Turkey, and the U.S. Central Command (USCENTCOM) area of responsibility.
- The Space Based Infrared System (SBIRS) is a satellite constellation of infrared sensors operated by the Air Force with an external interface to the BMDS located at Buckley AFB, Colorado.
- The list of BMDS sensors also includes the Aegis AN/SPY-1 radar. See the Aegis Ballistic Missile Defense (BMD) article (page 291) for reporting on this sensor.

- The C2BMC system is a Combatant Command interface to the BMDS and the integrating element within the BMDS. More than 70 C2BMC workstations are fielded at U.S. Strategic Command, U.S. Northern Command (USNORTHCOM), U.S. European Command (USEUCOM), U.S. Pacific Command (USPACOM), and USCENTCOM; numerous Army Air and Missile Defense Commands; Air and Space Operations Centers; Maritime Operation Centers; and other supporting warfighter organizations.
  - The current C2BMC provides Combatant Commands and other senior national leaders with situational awareness of BMDS status, system coverage, and ballistic missile tracks by displaying selective BMDS data for strategic/national missile defense and for theater/regional missile defense. The C2BMC does this by utilizing multiple message formats and diverse terrestrial and satellite communications paths.
  - The C2BMC also provides a consolidated upper echelon BMD mission plan at the Combatant Command and component level. BMDS elements (Aegis BMD, Ground-based Midcourse Defense (GMD), Patriot, and Terminal High-Altitude Area Defense (THAAD)) use their own command and control battle management systems and mission-planning tools for stand-alone engagements.

- The current C2BMC S6.4 suite provides command and control for the AN/TPY-2 (FBM) radar as well as track reporting to support weapon system cueing and engagement operations.
- BOA is a system within the C2BMC enterprise that receives raw infrared sensor information on boosting and midcourse ballistic objects and feeds that track data to C2BMC (S8.2-1 and beyond) for use in cueing BMDS sensors and weapon systems, and for situational awareness.
- Using the BMDS Communications Network, the C2BMC forwards AN/TPY-2 (FBM) and AN/SPY-1 tracks to GMD. C2BMC uses the Tactical Digital Information Link-Joint message formats to send C2BMC system track data to Aegis BMD, THAAD, Patriot, and coalition systems for sensor cueing and engagement support.

Mission

- Combatant Commands intend to integrate the BMDS sensors and C2BMC with other BMDS elements to intercept ballistic missile threats that target the United States and U.S. allies.
  - Combatant Commands use the BMDS sensors to detect, track, and classify/discriminate ballistic missile threats.
  - Combatant Commands use C2BMC for deliberate and dynamic planning; situational awareness; track management; AN/TPY-2 (FBM) sensor management and control; engagement support and monitoring, data exchange between C2BMC and BMDS elements; and network management.

Major Contractors

- COBRA DANE Radar: Raytheon Company, Intelligence, Information, and Services – Dulles, Virginia
- UEWRs: Raytheon Company (Prime), Integrated Defense Systems – Tewksbury, Massachusetts; Harris Corporation/Exelis (Sustainment) – Colorado Springs, Colorado
- SBX and AN/TPY-2 (FBM) Radars: Raytheon Company, Integrated Defense Systems – Tewksbury, Massachusetts
- SBIRS: Lockheed Martin Corporation, Space Systems – Sunnyvale, California
- C2BMC: Lockheed Martin Corporation, Rotary and Mission Systems – Huntsville, Alabama, and Colorado Springs, Colorado
- BOA: Northrop Grumman Corporation – Boulder, Colorado; Colorado Springs, Colorado; and Azusa, California

Activity

- The MDA conducted all testing in accordance with the DOT&E-approved Integrated Master Test Plan.
- The MDA used the sensors and/or the command and control architecture in six tests and five targets-of-opportunity data collections. The MDA conducted:

  - Two BMDS-level ground tests. The MDA conducted Ground Test, Integrated-07a (GTI-07a) in June 2017, assessing the BMDS Capability Increment 4 functionality improvements using strategic and theater/regional scenarios from USNORTHCOM's and USPACOM's

areas of responsibility. The MDA conducted Ground Test, Distributed-07a (GTD-07a) in September and October 2017. It complemented and included many of the same scenarios as GTI-07a, but in a distributed test environment. GTD ground tests use live operational networks, whereas GTI ground tests use laboratory-based networks.

- One GMD flight test. The MDA conducted Flight Test, Ground-Based Interceptor-15 (FTG-15) in May 2017, intercepting an ICBM-class target for the first time. FTG-15 was also the first intercept using the Capability Enhancement-II Block 1 exo-atmospheric kill vehicle and the first demonstration of the three-stage Configuration 2 booster.

- One Navy fleet exercise. In September and October 2017, the multi-event Formidable Shield-17 (FS-17) Navy fleet exercise was conducted. The firing (or simulated firing) ships prosecuted remote engagements using data from NATO maritime assets, transmitted by C2BMC through a NATO communications gateway.

- Two THAAD flight tests. The MDA conducted Flight Test, THAAD-18 (FTT-18) in July 2017. It was the first THAAD intercept of an intermediate-range ballistic missile target. The MDA conducted Flight Experiment, THAAD-01 (FET-01) in July 2017 to examine the THAAD element response to target dynamics. During both of these tests, the MDA used C2BMC S8.2-1 and BOA 5.1 for the first time.

- Radars from the sensor architecture collected data from five ballistic missile targets-of-opportunity during 2016.

• ARL/SLAD, in support of the MDA, conducted three cybersecurity events:

- In July 2017, ARL/SLAD evaluated USNORTHCOM's C2BMC S8.2-1.1, the C2BMC portion of the Cheyenne Mountain Management Node, the C2BMC Distributed Training System, and BOA 5.1 in a CVPA.

- In September 2017, ARL/SLAD conducted additional limited cooperative cybersecurity assessments on USNORTHCOM's C2BMC S8.2-1.1, BOA 5.1, and the AN/TPY-2 (FBM) radar CX2.1.1 configured with the Superdome computer processor. The C2BMC Program Office used this event to collect data on a prototype net defense tool that it intends to integrate into the C2BMC baseline.

- In October 2017, ARL/SLAD conducted a limited CVPA of the X-band radar (XBR) portion of the SBX.

• The Air Force conducted four ICBM reliability and sustainment flight tests using the MDA sensors and/or the command and control architecture. The Air Force conducted Glory Trip-221 (GT 221; February 2017), GT-220 (April 2017), GT-222 (May 2017), and GT-223 (August 2017) tests of the Minuteman III ICBM. For these four tests, the MDA provided the Space Tracking Surveillance System (GT 221), Enterprise Sensors Lab (GT 220 – GT 223), Mount Wilson Aerospace Facility for Integrated Optical Test (GT 220 – GT 223), Discrimination Sensor Technology (GT 221), Overhead Sensors (GT 220 – GT 223), and SBIRS (GT 221).

• The MDA completed the Sensor Analysis of Alternatives and presented the findings to the Missile Defense Executive Board in October 2016.

• The MDA initiated the defense of Hawaii radar program. Over FY17, initial analytical studies were completed and site surveys conducted.

• The MDA completed the Critical Design Review for the Long-Range Discrimination Radar in September 2017.

• The MDA integrated and accredited for developmental test C2BMC's Overhead Persistent Infrared (OPIR) simulation tools, Future OPIR External Simulation (FOXSIM) and On-Line Generic Adaptive Simulator (OLGASIM), to provide modeling and simulation representation of future sensor inputs to BOA 5.1. The BMDS Operational Test Agency team accredited the models for operational assessment.

Assessment

• During FTG-15, the GMD element performed nominally. The C2BMC S6.4-3.0 element forwarded SBIRS and AN/TPY-2 (FBM) CX-2.1 radar data to GMD Fire Control (GFC). GFC cued the SBX 3.3.1 radar. Based on correct SBX discrimination data, the GFC commanded a Mode 2 engagement. The Capability Enhancement-II Block 1 exo-atmospheric kill vehicle intercepted and negated the ICBM-representative reentry vehicle.

• ARL/SLAD's FY17 cybersecurity assessments of C2BMC, BOA, AN/TPY-2(FBM) radar, and XBR were the MDA's initial attempt at independent operational cybersecurity assessment to identify vulnerabilities on these systems. Real-world operational needs and lack of adherence to the test plans limited CVPA data collection during the September 2017 cybersecurity event.

• The cybersecurity assessments conducted in FY17 identified cybersecurity vulnerabilities; however, additional less restrictive testing (e.g., minimize "blacklisting;" full CVPA and AA team access to all systems and sub-systems that may introduce vulnerabilities to the BMDS architecture) is required to inform cybersecurity efforts, improve net defense, and characterize BMDS capability in a cyber-contested environment. This testing should include CVPAs and AAs that address previous CVPA limitations, other instantiations of C2BMC and AN/TPY-2, and other non-MDA sensors that are critical to BMDS capability (i.e., UEWRs and COBRA DANE).

• The MDA and the Army continue working to achieve Full Materiel Release of the AN/TPY-2 (FBM) radar. Of the 25 Initial Materiel Release conditions for software version CX-1.2.3_18, which includes 2 that the Army transferred from the CX-1.3.7 materiel release, the Army closed 5 prior to FY17 and an additional 4 in FY17. Further, the Army has drafted eight additional materiel release conditions for software version CX-2.1.0. The Army expects to close all remaining open materiel release conditions by 2019.

• The Army continues to transition AN/TPY-2 (FBM) radar operations and maintenance from contractor logistics support

to organic soldier operations and maintenance. Soldiers are now responsible for activities at two of the five deployed radars. Operator training and IETMs continue to be deficient.

- During FY17 ground testing, the MDA exercised new capabilities and assessed BMDS interoperability using hardware-in-the-loop simulation and operational assets communicating over operational networks (GTI-07a and GTD-07a, respectively). Test data informed enhanced homeland defense and theater/regional functionality development for BMDS Capability Increment 4 defined as:
  - BOA data integrated into the BMDS and providing X-band cues.
  - Ballistic missile defense planning, SBIRS interface change, and communications enhancements.
  - Performance improvements and Ground-Based Interceptor reliability upgrade.
  - Implement updated cybersecurity protections.
- During FTT-18 and FET-01, BOA 5.1 acquired and tracked the target, and transmitted the data to C2BMC S8.2-1 per the architecture design. C2BMC S8.2-1 demonstrated nominal situational awareness and track processing.
- During ballistic missile targets-of-opportunity in 2016, radars from the sensor architecture acquired, tracked, and reported track data to the GFC component. Truth data were also collected and the MDA's post-event data analysis confirmed that the overall system performed as designed.
- The MDA successfully conducted BMDS-associated operations on the Minuteman III target in all four FY17 Glory Trips. The MDA uses Glory Trips to reduce risk for future BMDS tests, exercise developmental capabilities, collect data for algorithm development and analysis, and to collect data for Critical Engagement Conditions and Empirical Measurement Events for model anchoring.
- The MDA demonstrated C2BMC S6.4 threat assessment, threat evaluation, sensor resource management, sensor track data processing, track reporting, target selection, sensor/weapon access determination, and engagement monitoring during flight tests, as well as during real-world ballistic missile targets-of-opportunity events. This software version does not enable automatic engagement coordination among different BMDS elements (e.g. THAAD and Aegis BMD).
- The MDA began ground testing of C2BMC S8.2, which will ultimately implement automatic engagement coordination, which the MDA currently plans for 2023. The MDA implemented a redundant unified client within C2BMC S8.2 that replaced the Global Engagement Manager and Combatant

Command suites implemented in C2BMC S6.4. The MDA is also implementing geographic C2BMC redundancy. The MDA plans to field C2BMC S8.2 to USNORTHCOM and USPACOM in FY18 followed by fielding to USEUCOM and USCENTCOM in FY19.

Recommendations
- Status of Previous Recommendations. The MDA has addressed previous sensors/command and control recommendations with three exceptions, two of which are classified. The MDA should:
  1. In conjunction with the Army, update the AN/TPY-2 (FBM) radar IETMs and improve radar operator training.
- FY17 Recommendations. The MDA should:
  1. Demonstrate C2BMC S8.2 internal failover capability (e.g., unified client string A to string B) and external geographic failover capability (e.g., USNORTHCOM to USPACOM) to assess C2BMC S8.2's ability to continue operations during an active engagement period.
  2. Develop a comprehensive operational cybersecurity test and evaluation strategy for each BMDS sensor and the C2BMC. This strategy should be included in the Integrated Master Test Plan and reflect the following:
     - Planned CVPAs of SBX and the AN/TPY-2 (FBM) radar configured with the x86 computer processor in FY18.
     - Planned AAs of the SBX; AN/TPY-2 (FBM) radar configured with the x86 computer processor; AN/TPY-2 (FBM) radar configured with the Superdome computer processor; C2BMC S6.4, C2BMC S8.2, and BOA in operational environments.
     - Coordination with the U.S. Air Force to conduct operational cybersecurity testing of the UEWRs and COBRA DANE radar.
     - Sufficient time to plan cybersecurity events, to ensure required resources are available to support adequate test conduct and enable timely resolution of key issues (e.g., sufficient detail in the test conduct, data management, analysis, and evaluation plans).
  3. Leverage and coordinate with ongoing cybersecurity assessment efforts to conduct operational cybersecurity assessments (CVPAs and AAs) of critical BMDS assets, in order to maximize efficiency and reduce duplication of activity across the DOD. These efforts include the DOT&E Cybersecurity Assessment Program, the Department's ongoing Persistent Cyber Operations, and the USD(AT&L) cybersecurity assessment efforts required by section 1647 of the National Defense Authorization Act for FY16.