Patriot Advanced Capability-3 (PAC-3)

Executive Summary
- The Army completed the Patriot Post-Deployment Build-8 (PDB-8) Developmental Test and Evaluation (DT&E) from July 2015 to July 2016.
- The Army conducted four Patriot flight tests and two Army Integrated Air and Missile Defense (AIAMD) flight tests using Patriot interceptors in FY16, achieving successful intercepts of all targets: five short-range ballistic missile (SRBM) targets, three cruise missile targets, and one fixed-wing aircraft target.
- The Army commenced the Patriot PDB-8 IOT&E in September 2016. This testing will continue through August 2017.

System
- Patriot is a mobile air and missile defense system that counters missile and aircraft threats. The newest version of Patriot hardware and software under development is PDB-8, which consists of improvements required to counter the evolving threat, to improve combat identification and the Air Defense Interrogator Mode 5 Identification, Friend or Foe (IFF) capability, to mitigate false tracks, to improve electronic protection, and to further integrate Missile Segment Enhancement (MSE) interceptor/ground system capabilities.
- The system includes the following:
  - C-band multi-function phased-array radars for detecting, tracking, classifying, identifying, and discriminating targets and supporting the guidance functions
  - Battalion and battery battle management elements
  - Communications Relay Groups and Antenna Mast Groups for communicating between battery and battalion assets
  - A mix of Patriot Advanced Capability-3 (PAC-3) hit-to-kill interceptors and PAC-2 blast fragmentation warhead interceptors for negating missile and aircraft threats
- The newest version of the PAC-3 interceptor under development is the PAC-3 MSE. The MSE provides increased battlespace defense capabilities and improved lethality over prior configuration Patriot interceptors.
- Earlier versions of Patriot interceptors include the Patriot Standard interceptor, the PAC-2 Anti-Tactical Missile, the Guidance Enhanced Missile (GEM) family (includes the GEM-T and GEM-C interceptor variants intended to counter tactical ballistic missiles and cruise missiles), the PAC-3 (baseline), and the PAC-3 Cost Reduction Initiative (CRI) variant.

Mission

Combatant Commanders use the Patriot system to defend deployed forces and critical assets from missile and aircraft attack and to defeat enemy surveillance air assets in all weather conditions and in natural and induced environments.

Major Contractors
- Prime: Raytheon Company, Integrated Defense Systems – Tewksbury, Massachusetts (ground system and PAC-2 and prior generation interceptors)
- PAC-3, PAC-3 CRI, and PAC-3 MSE Missiles: Lockheed Martin Corporation, Missile and Fire Control – Grand Prairie, Texas

Activity
- The Army conducted the Patriot PDB-8 DT&E from July 2015 to July 2016 at White Sands Missile Range (WSMR), New Mexico. The ground portion of this testing concluded in October 2015, with developmental flight tests occurring later:
  - In Flight Test P8-2 in November 2015, Patriot conducted a mixed ripple engagement of an SRBM target with PAC-3 CRI and PAC-2 GEM-T interceptors and then engaged a second SRBM target with two PAC-2 GEM-T interceptors.
  - In Flight Test P8-4 in December 2015, Patriot engaged an SRBM target with two PAC-3 MSE interceptors.
  - In Flight Test P8-3 in March 2016, Patriot conducted a mixed ripple engagement of an SRBM target with PAC-3 MSE and PAC-2 interceptors.
  - In Flight Test P8-1 in July 2016, Patriot engaged a cruise missile target with a PAC-2 GEM-T interceptor and then

engaged a maneuvering, full-scale, fixed-wing, air-breathing target with a PAC-3 MSE interceptor. The Army did not conduct this test in accordance with the DOT&E-approved Test and Evaluation Master Plan (TEMP), which stated that the fixed-wing aircraft would be employing electronic countermeasures while maneuvering. The Army has deferred testing of this capability to a Patriot PDB-8.1 flight test in 2020.

- The Army conducted two AIAMD flight tests at WSMR during FY16 using Patriot interceptors:
  - In AIAMD Flight Test-1 (FT-1) in November 2015, Patriot engaged a cruise missile target with a PAC-3 interceptor.
  - In AIAMD FT-3 in April 2016, Patriot engaged an SRBM target with one PAC-3 interceptor and conducted two separate PAC-2 GEM-T engagements against a cruise missile target, with the first engagement resulting in a missed intercept and the second engagement resulting in a successful intercept.
- The Army conducted lethality testing of the PAC-3 MSE lethality enhancer titanium fragments against Composition B explosive from July 2015 through June 2016 at Aberdeen Proving Ground, Maryland, to update the lethality model that predicts when a high-explosive initiation occurs within a warhead impacted by fragments.
- The Army conducted all testing in accordance with the DOT&E-approved TEMP and/or test plans, with the exception of the previously discussed P8-1 flight test and the PDB-8 flight test against an anti-radiation missile, which the Army deferred to a Patriot PDB-8.1 flight test in 2021 due to the lack of an available target.
- The Army commenced the Patriot PDB-8 IOT&E in September 2016 at Yuma Proving Ground, Arizona. The IOT&E, which will include flight tests conducted at WSMR and the Reagan Test Site at the Kwajalein Atoll in the Marshall Islands, will continue through August 2017. The IOT&E will provide information to support the PAC-3 MSE Full-Rate Production decision and the Army's deployment of Patriot PDB-8.
- The 2016 National Defense Authorization Act directs that the Missile Defense Agency and the Army conduct at least one intercept flight test each year that demonstrates interoperability and integration among the covered air and missile defense capabilities of the United States. In response to this act, Aegis Ballistic Missile Defense (BMD) will participate in Patriot's final operational flight test in FY17 as a forward-based sensor.

Assessment

- Problems previously discovered during the PDB-7 Limited User Test (LUT), if not corrected by the Army, could adversely affect Patriot PDB-8 effectiveness, suitability, or survivability. These problems, the details of which can be found in DOT&E's classified April 2013 Patriot PDB-7 LUT report, include:
  - Patriot PDB-7 performance against some threats improved compared to PDB-6.5, but there were degradations in performance against other threats. Patriot had some effectiveness shortfalls.
  - Patriot ground system reliability did not meet the threshold requirement, but would have met it had the Patriot radar achieved its allocated reliability goal.
  - Patriot ground system maintainability did not meet the threshold requirement.
  - Patriot training remained inadequate to prepare operators for complex Patriot engagements. This was also true during the PDB 6.5 and PDB-6 LUTs.
  - Patriot had some survivability and cybersecurity shortfalls.
- The Patriot system met most of its test objectives during the Patriot PDB-8 DT&E, but not all. During the ground test portion using simulated interceptors and mostly simulated targets, Patriot did not always properly transmit messages; detect, classify, and discriminate targets; or select the preferred interceptors against targets (e.g., Patriot would sometimes incorrectly select a PAC-2 GEM against a fast tactical ballistic missile or a PAC-3 interceptor against a threat aircraft).
  - There were anomalies in the Patriot PDB-8 implementation of IFF, which led to over-interrogations and indicated degradation from the previously demonstrated PDB-7 IFF capability. The Army updated the PDB-8 software to correct these problems and the fixes will be verified during IOT&E.
  - Patriot PDB-8 Training Software sometimes generated spurious alerts and improperly displayed some scripted targets.
  - The Patriot system did not meet its reliability requirements during this test.
- During Flight Test P8-2, Patriot demonstrated the capability to detect, track, engage, intercept, and kill an SRBM target with a mixed ripple method of fire using PAC-3 CRI and PAC-2 GEM-T interceptors and a second SRBM target with two PAC-2 GEM-T interceptors. In both instances, the first interceptor in the ripple intercepted and killed the target at the planned altitude, and performance of the ground system and interceptor was nominal.
- During Flight Test P8-4, Patriot demonstrated the capability to detect, track, engage, intercept, and kill an SRBM target with two PAC-3 MSE interceptors. The first PAC-3 MSE intercepted and killed the target at the planned altitude, and performance of the ground system and interceptor was nominal, although some post-intercept ground system anomalies occurred that did not affect the mission objectives.
- During Flight Test P8-3, Patriot demonstrated the capability to detect, track, engage, intercept, and kill an SRBM target with a mixed ripple method of fire using a PAC-3 MSE and a PAC-2 GEM-T interceptor. The PAC-3 MSE (the first interceptor) intercepted and killed the target at the planned altitude and both ground system and interceptor performance was generally nominal, although a Link-16 network initialization problem prevented the demonstration of Patriot PDB-8 interoperability on Link-16 during this flight test. Other parts of the Patriot PDB-8 DT&E demonstrated Link-16 interoperability.

- During Flight Test P8-1, Patriot demonstrated the capability to detect, track, engage, intercept, and kill a low-radar cross section cruise missile target at low altitude and in a clutter environment with a PAC-2 GEM-T interceptor and, following this, a maneuvering full-scale aircraft target with a PAC-3 MSE interceptor. The interceptors killed both targets at the planned ranges and altitudes, and performance of the ground system and interceptors were nominal for both engagements. Patriot demonstrated PDB-8 interoperability on Link-16 during this flight test.
- During AIAMD FT-1, Patriot demonstrated the capability to engage, intercept, and kill a low-altitude cruise missile target with a PAC-3 interceptor based on remote Sentinel radar data sent through an AIAMD Battle Command System Engagement Operations Center.
- During AIAMD FT-3, Patriot demonstrated the capability to detect, track, engage, intercept, and kill an SRBM target using a PAC-3 interceptor and a cruise missile target with the second of two PAC-2 GEM-T interceptors after the first GEM-T missed.
- The PAC-3 MSE lethality enhancer testing showed that the existing lethality model for titanium did not predict, within 10 percent of the observed critical velocities, when a high-explosive initiation of a warhead would occur. The Army used these results to develop new coefficients for their lethality model that more accurately represent the PAC-3 MSE titanium fragments.

Recommendations

- Status of Previous Recommendations. The Army satisfactorily addressed 15 of the previous 23 recommendations. The Army should continue to address the following recommendations:
  1. Conduct Patriot air and missile defense testing during joint and coalition exercises that include large numbers of different aircraft types, sensors, battle management elements, and weapons systems. Additionally, the Army should conduct Red Team Adversarial Assessments during joint exercises to test Patriot cybersecurity.
  2. Conduct a Patriot flight test against an anti-radiation missile target to validate models and simulations.
  3. Improve Patriot training to ensure that Patriot operators are prepared to use the system in combat.
  4. Have Patriot participate with live interceptors in Terminal High Altitude Area Defense (THAAD) flight testing to determine Patriot-to-THAAD interoperability and the capability for Patriot to intercept tactical ballistic missile targets that THAAD does not intercept.
  5. Collect operational reliability data on Patriot systems in the field so that the Mean Time Between Critical Mission Failure can be calculated.
  6. Use test units for future Patriot operational tests that have operationally representative distributions in soldier proficiency.
  7. Conduct future operational flight tests with unannounced target launches within extended launch windows.
  8. Improve Patriot radar reliability.
- FY16 Recommendations. The Army should:
  1. Conduct a simultaneous engagement of a cruise missile target with a PAC-2 GEM-T interceptor and a maneuvering full-scale fixed-wing aircraft target employing electronic countermeasures with a PAC-3 MSE interceptor.
  2. Have Patriot participate with live interceptors in Aegis BMD flight testing to determine Patriot-to-Aegis BMD interoperability and the capability for Patriot to intercept ballistic missile targets that Aegis BMD does not intercept.