# Patriot Advanced Capability-3 (PAC-3)

**Executive Summary**

- The Army began the Post-Deployment Build-7 (PDB-7) Limited User Test (LUT) operational test in FY12. The PDB-7 LUT included hardware-in-the-loop (HWIL) testing, sustained operations testing, and a combined missile flight test that consolidated three individual missile flight tests into one campaign.
- The Army conducted five major developmental Patriot flight test missions and the PDB-7 Developmental Test and Evaluation (DT&E) in FY12.
- The Missile Defense Agency conducted an integrated flight test of the Ballistic Missile Defense System (BMDS) in October 2012, during which Patriot engaged and killed a cruise missile target and a tactical ballistic missile target in the debris field caused by another BMDS intercept.
- In the seven U.S. developmental and operational flight tests conducted in FY12, Patriot achieved successful intercepts of six short-range ballistic missile targets and five air-breathing threat/cruise missile targets using Patriot Advanced Capability-3 (PAC-3) and Guidance Enhanced Missile (GEM) missiles.
- The Army also conducted five flight tests for an international Foreign Military Sales (FMS) customer, during which Patriot intercepted four of five tactical ballistic missile targets and three of three air-breathing threat/cruise missile targets. The fifth FMS flight test concurrently successfully fulfilled a long standing PAC-3 Engineering Manufacturing and Development phase requirement.

**System**

- Patriot is a mobile air and missile defense system that counters missile and aircraft threats. The system includes the following:
  - C-band phased-array radars for detecting, tracking, classifying, identifying, and discriminating targets
  - Battalion and battery battle management elements
  - Communications Relay Groups and Antenna Mast Groups for communicating between battery and battalion assets
  - A mix of PAC-3 hit-to-kill missiles and PAC-2 blast fragmentation warhead missiles for negating missile and aircraft threats
- The newest version of the PAC-3 missile is the Cost Reduction Initiative (CRI) missile. In addition, the Army is developing the PAC-3 Missile Segment Enhancement (MSE) missile with increased battlespace defense capabilities and improved lethality.
- Earlier versions of Patriot missiles include the Patriot Standard missile, the PAC-2 Anti-Tactical Missile, and the GEM family (includes the GEM-T and GEM-C missile variants intended to counter tactical ballistic missiles and cruise missiles, respectively).
- DoD intended the Medium Extended Air Defense System (MEADS) to replace the Patriot system. The DoD has decided not to field MEADS and plans to conclude the design and development phase of the program in FY13.

**Mission**

Combatant Commanders use Patriot to defend deployed forces and critical assets from missile and aircraft attack and to defeat enemy surveillance air assets (such as unmanned aerial vehicles) in all weather conditions, and in natural and induced environments.

**Major Contractors**

- Raytheon Integrated Defense Systems – Tewksbury, Massachusetts
- Lockheed Martin Missile and Fire Control – Grand Prairie, Texas

**Activity**

- In accordance with the DOT&E-approved Test and Evaluation Master Plan, the Army began the PDB-7 LUT on May 31, 2012, at White Sands Missile Range (WSMR), New Mexico. The PDB-7 LUT is expected to end in November 2012 with the completion of the PDB-7 LUT regression test.

- The Army conducted the PDB-7 LUT operational missile flight test (P7L-1/2/3) at WSMR in August 2012. During this test, Patriot:
  - Engaged and intercepted one tactical ballistic missile target with a ripple launch (firing of missiles in quick succession) of GEM-T/PAC-3 CRI missiles.
  - Engaged a second tactical ballistic missile target with a ripple launch of two PAC-3 missiles. This second tactical ballistic missile target self-destructed before the interceptors reached it; therefore, the endgame segment of the second tactical ballistic missile engagement was deemed a "No Test."
  - Engaged and intercepted a cruise missile target with a GEM-T missile in the debris field resulting from the destruction of the two tactical ballistic missile targets.
- The Army conducted the PDB-7 DT&E at WSMR from July 2011 to March 2012.
  - During PDB-7 flight test P7-4 in November 2011, Patriot engaged a short-range ballistic missile target with a ripple launch of two PAC-3 CRI missiles. The first PAC-3 missile intercepted the target.
  - During PDB-7 flight test P7-3 in November 2011, Patriot engaged a short-range ballistic missile target with a ripple launch of two GEM-T missiles. The first GEM-T missile intercepted the target.
  - During PDB-7 flight test P7-2 in November 2011, Patriot engaged two short-range ballistic missile targets with two ripple launches of GEM-T/GEM-C missiles. The first GEM-T missile of each ripple engagement intercepted its target.
  - During PDB-7 flight test P7-1 in March 2012, Patriot fired a GEM-T missile at one cruise missile target and a GEM-C missile at a second cruise missile target. Both Patriot missiles intercepted their targets.
- During the first Integrated Fire Control flight test (IFC-1) at the Utah Test and Training Range in April 2012, Patriot fired a PAC-3 CRI missile at a cruise missile target using a Joint Land Attack Cruise Missile Defense Elevated Netted Sensor System cue. The PAC-3 missile intercepted the target.
- During the first MEADS flight test, the Launcher/Missile Characterization Test at WSMR in November 2011, MEADS fired an MSE missile at a simulated target.
- During the FMS G-2 missile flight test at WSMR in March 2012, Patriot intercepted a cruise missile target with a GEM-T missile.
- During the FMS P-1/P-2 missile flight test at WSMR in March 2012, Patriot engaged a short-range ballistic missile target with a ripple launch of two PAC-3 missiles. The first PAC-3 missile intercepted the target.
- During the FMS G-3/G-6/G-7 missile flight test at WSMR in May 2012, Patriot failed to intercept a short-range ballistic missile target during the G-3 portion of the mission because of a missile launch sequence failure. As a result, the G-3 portion of the mission was repeated using a backup short-range ballistic missile target, which Patriot intercepted using a GEM-T missile. This was followed by the launch of another short-range ballistic missile target, which Patriot engaged using a ripple launch of two GEM-T missiles. The first GEM-T missile intercepted the target.
- During the FMS G-4/G-5 missile flight test at Eglin AFB, Florida, in June 2012, Patriot performed near-simultaneous intercepts over water of two air-breathing targets using GEM-T missiles.
- During the FMS P-3/P-4 missile flight test at WSMR in September 2012, Patriot engaged a short-range ballistic missile target with a ripple launch of two PAC-3 CRI missiles. The first PAC-3 missile intercepted the target. This mission concurrently fulfilled a long standing PAC-3 Engineering Manufacturing and Development phase requirement.
- During Flight Test Integrated-01 (FTI-01) in October 2012 at the Reagan Test Site, Patriot performed a near-simultaneous engagement of a short-range ballistic missile target with two PAC-3 interceptors and a cruise missile target with another PAC-3 interceptor. FTI-01 was the first integrated flight test with multiple firing elements (Aegis Ballistic Missile Defense [BMD], Terminal High-Altitude Area Defense [THAAD], and Patriot) engaging multiple ballistic missile and air-breathing targets in a realistic BMDS-level architecture. Patriot successfully intercepted both of its targets.

**Assessment**

- The HWIL phase of the PDB-7 LUT was to have included equal numbers of runs with and without simulated MSE missiles. All planned runs without MSE missiles were completed, but Patriot system availability problems led to only 20 percent of the MSE runs being accomplished. As a result, the effectiveness assessment of the Patriot PDB-7 system with MSE missiles will be limited until the Army conducts a dedicated HWIL test with simulated MSE missiles. Additional HWIL testing with MSE missiles is planned as part of PDB-7 regression testing scheduled to complete in November 2012.
- Data analysis is ongoing, but preliminary results indicate that Patriot training remains inadequate to prepare operators for complex Patriot engagements. This was true during the PDB-6.5 and PDB-6 LUTs as well. This problem was exacerbated in the PDB-7 LUT because many of the experienced Patriot operators in the test unit were understandably transferred to deploying units prior to the LUT, resulting in many inexperienced users and a high variability in Soldier proficiency across the test unit.
- Calculation of Patriot system reliability such as Mean Time Between Critical Mission Failure using field data is being investigated. Critical field data including total operating hours and numbers of critical mission failures for each Patriot battery major end item may not be accurate.
- During the PDB-7 LUT operational missile flight test (P7L-1/2/3), Patriot demonstrated the capability to search, detect, track, engage, and intercept both a tactical ballistic missile target and a cruise missile target with GEM-T missiles. Patriot intercepted the cruise missile target in the debris field caused by the intercept of the first tactical ballistic missile target and the self-destruction of the second tactical ballistic

missile target. However, the following problems were observed during this test:
  - Patriot was to have engaged the first tactical ballistic missile target with two GEM-T missiles, but the launcher incorrectly reported a missile count of zero after the first GEM-T missile launched so a PAC-3 missile was launched instead.
  - Patriot engaged the second tactical ballistic missile target with two PAC-3 missiles, but the target broke up before the missiles reached it. The cause of this target failure is under investigation.
  - Patriot was to have had two GEM-T missiles available to engage the cruise missile target, but one could not be armed. The backup missile was not needed however, as the first GEM-T missile launched successfully and intercepted the target.
  - Although the Patriot crews were not supposed to be notified when the targets were launched, a test conduct error led to them hearing the range communications network during the launches. It is unknown what effect, if any, this had on the test.
- The Patriot system met most of the test objectives during the PDB-7 DT&E. However, there were some incidents during the ground testing portion when Patriot did not properly transmit messages, had degraded track triangulation between batteries, was unable to isolate faults and had to be rebooted, selected a launcher with no available missiles, and selected less preferred missiles against threats (e.g., a GEM against a long-range tactical ballistic missile or a PAC-3 missile against a threat aircraft). The Patriot system did not meet its reliability requirements during this test.
- During PDB-7 flight test P7-4, Patriot demonstrated the capability to search, detect, track, engage, and intercept a tactical ballistic missile target with PAC-3 missiles in a ripple engagement. There were some discrepancies between the performance of the second PAC-3 missile during its initial turn and pre-flight simulations. The causes of these discrepancies are still under investigation. One of the two non-firing Patriot batteries did not collect data during the P7-4 flight test. The affected non-firing battery restarted the data collection system multiple times in an effort to fix the problem, but it was not resolved before the engagement.
- During PDB-7 flight test P7-3, Patriot demonstrated the capability to search, detect, track, engage, and intercept a tactical ballistic missile target with GEM missiles in a ripple engagement.
- During PDB-7 flight test P7-2, Patriot demonstrated the capability to detect, engage, and intercept short-range ballistic missile targets with GEM-T missiles. Patriot conducted the second engagement in the presence of the debris cloud caused by the first intercept.
- During PDB-7 flight test P7-1, Patriot demonstrated the capability to detect, engage, and intercept cruise missile targets in clutter with GEM-T and GEM-C missiles.
- During IFC-1, Patriot demonstrated the capability to use the Joint Land Attack Cruise Missile Defense Elevated Netted Sensor System cuing data to engage a cruise missile with a PAC-3 missile. The PAC-3 missile intercepted the target.
- During the Launcher/Missile Characterization Test, an MSE missile was launched at a 70-degree angle, performed an out-of-plane maneuver, and followed the predicted flight path to the simulated target, which was 120 degrees off the launch axis. All test objectives were met.
- Patriot intercepted four of five tactical ballistic missile targets and three of three air-breathing threat/cruise missile targets during five FMS flight tests.
  - The original target in the FMS G-3 missile flight test was to be engaged with only one GEM-T missile, but the GEM-T missile had a launch sequence failure and there was not an active back-up missile that could launch in its place. After this failure, a back-up tactical ballistic missile target and back-up GEM-T missile were activated. The back-up GEM-T missile engaged and intercepted the back-up tactical ballistic missile target.
  - The FMS G-6/G-7 missile flight test was a GEM-T ripple engagement of another tactical ballistic missile target in the debris caused by the G-3 intercept. The first GEM-T had a launch sequence failure. However, there was a live back-up missile for this engagement so two GEM-T missiles were launched, the first of which intercepted the target.
- During FTI-01, Patriot demonstrated the capability to detect, track, engage, intercept, and kill both a tactical ballistic missile target and a cruise missile target with PAC-3 missiles. There was a Patriot radar fault between the cruise missile and ballistic missile engagements, but the system recovered and was able to conduct a nominal engagement. The root cause of the radar fault is under investigation. All PAC-3 missile subsystems performed as expected. The Patriot engagements were conducted in the debris field from the THAAD intercept and Patriot debris mitigation was nominal. Aegis BMD failed to intercept its ballistic missile target during FTI-01. The Missile Defense Agency did not set up the flight test so Patriot could intercept targets that Aegis or THAAD missed, although DOT&E had recommended this be a feature of BMDS flight testing (previous recommendation #6 below).
- Continuing obstacles to adequate T&E of the Patriot system include:
  - Limitations to the lethality information available for aircraft, cruise missile, and air-to-surface missile threats used to assess end-to-end system effectiveness.
  - The lack of a robust interoperability event during PDB-7 testing.
  - The lack of a robust Force Development Experiment, preventing the Army from thoroughly examining tactical standard operating procedures prior to developing Patriot PDB-7 tactics, techniques, and procedures. As a result, the engagement procedures used during the PDB-7 LUT against some threats may have led to decreased system performance.

**Recommendations**

- Status of Previous Recommendations. The Army satisfactorily addressed 10 of the previous 18 open recommendations. The Army should still address the following recommendations:
  1. Conduct Patriot testing during joint and coalition exercises.
  2. Upgrade the Patriot HWIL systems to model electronic countermeasures and identification friend-or-foe systems.
  3. Conduct a Patriot flight test against an anti-radiation missile target to validate models and simulations.
  4. Review the risks of not conducting all flight tests against ballistic missile targets using two interceptors.
  5. Improve Patriot training.
  6. Have Patriot participate with live interceptors in THAAD flight testing.
  7. Conduct all operational testing regression tests with representative Soldier operators.
  8. Conduct a robust Force Development Experiment prior to the PDB-8 IOT&E to ensure that tactics, techniques, and procedures are adequate to support a successful operational test.
- FY12 Recommendations. In addition to addressing the above recommendations, the Army should:
  1. Collect reliability data on Patriot systems in the field, including total operating hours and numbers of critical mission failures for each Patriot battery major end item, so that the Mean Time Between Critical Mission Failure can be calculated.
  2. Ensure that test units for future Patriot operational tests have operationally representative distributions in Soldier proficiency by limiting transfers of experienced personnel to other units before the end of testing.
  3. Conduct future operational flight tests with unannounced target launches within extended launch windows to improve operational realism.