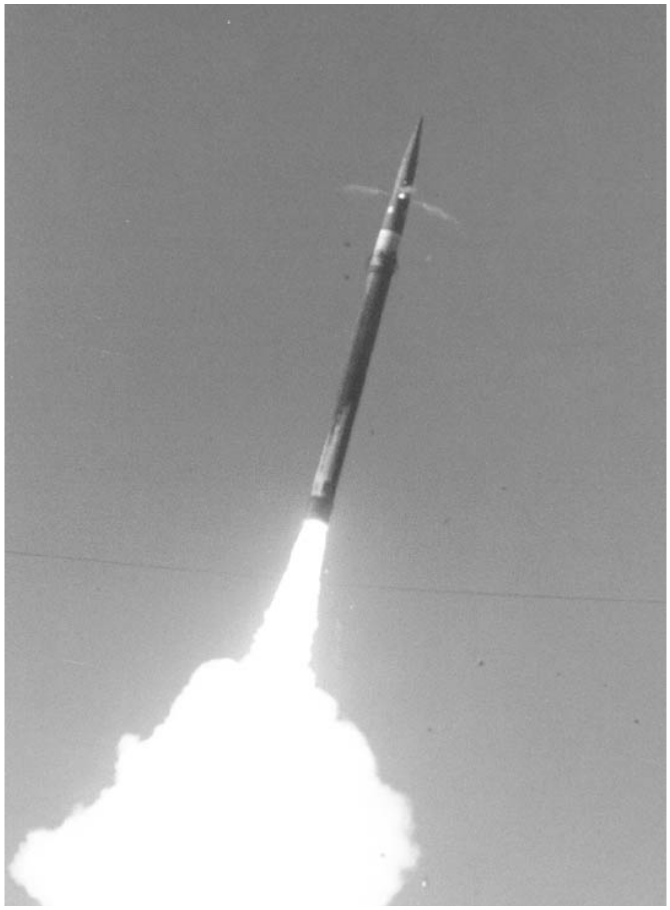
THEATER HIGH ALTITUDE AREA DEFENSE (THAAD)



Army ACAT ID Program		**Prime Contractor**
Total Number of Missiles:	1,233	Lockheed Martin Missiles and Space
Total Program Cost (TY$):	$17,600M	Sunnyvale, CA
Average Unit Cost (TY$):	$5.3M	
Full-rate production:	FY10	

SYSTEM DESCRIPTION & CONTRIBUTION TO JOINT VISION 2010

The Theater High Altitude Area Defense (THAAD) is a mobile ground-based theater missile defense (TMD) system designed to protect forward-deployed military forces, population centers, and civilian assets from Theater Ballistic Missile (TBM) attacks. THAAD negates incoming ballistic missiles utilizing hit-to-kill technology (i.e., kinetic warhead) and is capable of intercepting them at either endoatmospheric or exoatmospheric altitudes. As a core element of the Family of Systems layered defense architecture, it provides upper-tier missile defense in concert with the lower-tier systems, PATRIOT Advanced Capability-3 (PAC-3) and Navy Area TMD.

The THAAD system is comprised of mobile launchers, interceptors, radars, battle management/command, control, communications, and intelligence (BM/C^3I) units, and ground support equipment. The launcher system is a modified U.S. Army palletized loading system truck, equipped with a missile-round pallet. The interceptor consists of a single-stage, solid-fuel booster—which employs thrust vector control technology for boost phase steering—and a separating kill vehicle that uses an infrared seeker and divert thrusters for terminal guidance and control. The THAAD radar is a solid-state, X-band, phased-array antenna that performs search, track, threat type classification, and interceptor fire control functions. As the communications link between the BMC^{3}I and interceptors, the THAAD radar also delivers target updates to the kill vehicle, which it uses for midcourse guidance. The THAAD BM/C^{3}I segment manages and integrates all THAAD components to control the THAAD weapon system. Its major components are the Tactical Operations Center, the Sensor System Interface, and the Communications Relay, which are transported on High Mobility Multi-Purpose Wheeled Vehicles.

THAAD embodies ***Joint Vision 2010's*** operational concepts of ***dominant maneuver***, ***precision engagement***, and ***full-dimensional protection***: THAAD is a mobile, integrated system of elements that provides responsive command and control to locate and engage attacking TBMs. ***Information superiority*** enables THAAD to operate within a communications network, receiving and exchanging data with external sensors, PAC-3, Navy Area, and other theater air and missile defense systems. Furthermore, THAAD is designed to rapidly respond to military crises and, therefore, incorporates the fourth operational concept of ***focused logistics***.

BACKGROUND INFORMATION

The Gulf War demonstrated an immediate need for an effective and dedicated missile defense system capable of countering TBM attacks. Recognizing this need, Congress passed the National Missile Defense Act of 1991 and the Defense Appropriations Act of 1991, which established the requirement for a "deployable TMD demonstration system" for forward-deployed U.S. and Allied Forces by the mid 1990s. A mature system with full capabilities was to be developed by the year 2000. To implement this requirement, Congress directed the Secretary of Defense to pursue advanced TMD options aggressively, with the objective of down-selecting and deploying such systems by the mid 1990s.

The long-term response to this requirement is the development and eventual deployment of the THAAD "objective" system during the EMD phase of development. The THAAD User Operational Evaluation System (UOES), now terminated, would have been the demonstration system using prototype equipment to perform early operational assessments and deploy in the event of a "national emergency" contingency operation. The program is being significantly restructured. A Milestone II decision is currently scheduled for FY00.

Currently, THAAD is planning to meet its ORD requirements through two sequenced configurations, both developed during EMD, employing an "Evolutionary Acquisition" approach. The Configuration-2 system delivers full ORD compliance. The Configuration-1 system provides a significant warfighting capability while deferring some software (time-intensive) development for the BMC^{4}I and Radar to Configuration-2. The Army "User" defines details of the Configuration-1 capability.

THAAD has an approved TEMP from Milestone I. The draft Milestone II TEMP staffing is on hold pending program restructuring. The ORD is being updated to support the Milestone II decision.

TEST & EVALUATION ACTIVITY

THAAD achieved target intercepts in Flight Test (FT) 10 and 11. Subsequently, the Department authorized the Army to suspend PDRR phase testing and prepare to enter the EMD phase. For clarity, this report provides a summary of the entire PD&RR THAAD test program activities.

The PD&RR phase of the THAAD program contained no operational testing, however, the Army and OSD Test and Evaluation (T&E) communities participated early in the planning and execution of PD&RR testing. Operational assessments using PD&RR data supported key program decisions. Such assessments depend on system-level as well as element-level test results.

The THAAD PD&RR T&E program consists of the execution of system flight testing, hardware-in-the-loop (HWIL) testing, element ground testing, and digital simulations. Flight testing is the centerpiece of the T&E program and was conducted at White Sands Missile Range (WSMR). Successful flight tests allow testers and developers to collect system-level data, assess kill vehicle seeker technology and intercept capability, and generate a wealth of in-flight environmental and "end game" data, which ultimately lead to improvements in the design of system hardware and software. Such data are also used to validate models and simulations supporting system evaluations.

The program has completed eleven Program Definition and Risk Reduction (PD&RR) flight tests, including eight intercept attempts. The first six of eight intercept attempts failed to achieve an intercept, but the last two intercept attempts flying the Block Upgrade interceptor were successful.

- Flight Test #1 (Propulsion Test – 4/95). No target was flown on this flight test. This flight successfully demonstrated interceptor launch, booster performance, booster/kill vehicle separation, radar-interceptor communication feasibility, flight termination system operation, and in-flight environmental data collection.

- Flight Test #2 (Controls Test – 7/95). No target was flown on this flight test. This flight demonstrated the successful performance of the kill vehicle guidance and control system. The kill vehicle performed mid-course guidance based on navigation updates sent from simulated THAAD radar using WSMR instrumentation radar data. Since the flare on the interceptor booster failed to deploy, the burnout velocity was higher than WSMR's pre-set range safety threshold, and WSMR safety personnel terminated the mission early.

- Flight Test #3 (Seeker Characterization Test – 10/95). The collection of kill vehicle seeker data was the primary objective of this flight test. The interceptor successfully executed an intentional fly-by of a STORM ballistic missile target for data collection. This flight also demonstrated early BMC^3I and launcher integration, launch and booster performance, fire control solution, and kill vehicle closed-loop navigation and guidance.

- Flight Test #4 (Intercept Attempt – 12/95). This was the first flight test in which the primary objective was to intercept a STORM ballistic missile target. This objective was not met. The kill vehicle entered the final phase of the engagement and successfully acquired, designated, and tracked the target. However, the kill vehicle could not perform final divert maneuvers because its divert fuel depleted prematurely. Post-flight analyses indicate that a software error in avionics processing, combined with erroneous WSMR range radar data, caused the kill vehicle to divert off course, which lead to an excessive consumption of divert fuel. The kill vehicle never entered the final "terminal mode" of the engagement phase, in which the kill vehicle actively homes in on the target.

- Flight Test #5 (Intercept Attempt – 3/96). The primary objective of FT-5 was to intercept a HERA ballistic missile target, an objective that was not achieved. The failure occurred at kill vehicle separation from the booster when one of the four separation connectors failed to disconnect. The onboard avionics computer was reset and failed to perform the processing required for guiding the kill vehicle to an intercept.

- Flight Test #6 (Intercept Attempt – 7/96). The sixth flight test was an attempt to intercept a HERA ballistic missile target in the high endoatmosphere. An intercept was not achieved. A problem with either the seeker electronics or a contaminated Dewar caused one half of the infrared focal plane array to saturate. This overloaded the onboard signal processor, which precluded designation of the target and resulted in no closed-loop guidance of the kill vehicle. The target was visible on the focal plane telemetry data.

- Flight Test #7 (Intercept Attempt – 3/97). The seventh flight test was a repeat of FT-6, with the primary objective to intercept a HERA ballistic missile target in the high endoatmosphere. This flight failed to achieve an intercept because contamination on the missile battery interface resulted in poor electrical contact and prevented the operation of the Divert and Attitude Control System thrusters. As a result, the kill vehicle did not perform attitude and divert control maneuvers necessary for acquiring and intercepting the target. FT-7 was the first flight test during which the THAAD radar actively participated as the prime surveillance and fire control sensor. All previous flight tests used WSMR range radars to track the targets and interceptors and provide in-flight updates. Of these flight tests, the THAAD radar participated in a track only "shadow" mode on FT-03 through FT-06.

- Flight Test #8 (Intercept Attempt – 5/98). After a fourteen-month period of ground testing and pedigree review, FT-8 was executed. Its primary objective was to intercept a HERA ballistic missile target in the high endoatmosphere, a repeat of FT-6 and FT-7. The interceptor lost control immediately after launch and self-destructed after 6 seconds of flight time—without an intercept. The failure is attributed to an electrical short circuit due to foreign object debris in the high-voltage connector in the thrust vector control system that steers the booster.

- Flight Test #9 (Intercept Attempt – 3/99). The ninth flight test was a repeat of FT-8, with the primary objective to intercept a HERA ballistic missile target in the high endoatmosphere. This flight failed to achieve an intercept. Although the kill vehicle came within meters of intercepting the target, no endgame data was collected because the telemetry system was damaged during interceptor fly-out. Both failures—the missed intercept and loss of telemetry—resulted from very high internal environments in the kill vehicle which occurred after an attitude control system nozzle was torn from its bracket approximately 23 seconds into flight.

- Flight Test #10 (Intercept Attempt – 6/99). The tenth flight test was a repeat of FT-9, with the primary objective to intercept a unitary HERA ballistic missile target in the high endoatmosphere. The first flight test to fly the Block Upgrade interceptor, THAAD FT-10, achieved body-to-body intercept by successfully hitting within the specification aimpoint limits on the warhead region of the target. Furthermore, FT-10 demonstrated THAAD system integration and closed-loop operation as well as excellent performance by all THAAD elements. All flight test objectives were achieved.

- Flight Test #11 (Intercept Attempt – 8/99). The eleventh flight test was a successful attempt by the THAAD system to intercept a separated HERA reentry vehicle target in the exoatmosphere. Flying the Block Upgrade interceptor, THAAD FT-11 achieved body-to-body intercept of the reentry vehicle under conditions more stressing than those found in FT-10. The kill vehicle not only engaged a dimmer target, it fused radar discrimination data with its own onboard infrared seeker data to correctly choose the reentry vehicle target from the spent second stage of the HERA. Like FT-10, THAAD demonstrated system integration and closed-loop operation, as well as excellent performance by all THAAD elements. The impact distance from the aimpoint was well within the requirement.

The Department decided to stop PD&RR testing following the intercepts achieved in Flight Tests 10 and 11 because large portions of the THAAD system will be redesigned for EMD. The early developmental tests in EMD are planned at WSMR and Kwajalein to prove out the new redesign prior to committing to the production configuration. The THAAD missile redesign features between PD&RR and EMD include:

- New missile mission computer.

- New cylindrical missile canister.

- Elimination of course elevation gimbal gyro.

- New Divert and Attitude Control System fuel tank with 40 percent more fuel, located aft of the divert thrusters.

- Relocation of missile avionics to accommodate center of mass change due to new Divert and Attitude Control System fuel tank.

- Increase in Divert and Attitude Control System thrust by 10 percent.

- An improved thrust vector control system on the booster.

Live Fire Test and Evaluation (Lethality). Recent THAAD lethality testing has focused on emerging targets described in the Ballistic Missile Requirements Document. In FY98, the Army conducted a series of eight quarter-scale light gas gun tests against a heavily ballasted submunition target at the University of Alabama-Huntsville gas gun range. Those tests showed that THAAD could have a high lethality against that target under a wide range of conditions. In FY99, another series of four light gas gun tests against a submunition warhead of similar design, but with a different fill, was conducted at the Huntsville range. Those tests also showed that THAAD could be lethal against the target under a wide range of conditions. Previously during FY95, the program conducted 15 static sled tests at Holloman Air Force Base, NM, to study system lethality. A series of ten quarter-scale light-gas-gun tests, conducted at the University of Alabama-Huntsville to obtain more lethality information, was completed in October 1996. These lethality tests provide the baseline for planning formal LFT&E for EMD. In 1996, DOT&E approved THAAD's live fire strategy.

TEST & EVALUATION ASSESSMENT

The THAAD program has made significant progress by achieving two hit to kill intercepts with high accuracy. The two intercepts demonstrated integrated system performance among the missile, radar, and BMC^3I. A spring 2000 DAB will consider whether to move the program into the EMD phase given these two intercepts and the program meeting most of the Milestone II exit criteria. DOT&E supports the decision to terminate testing on the PDRR missile and focus efforts on engineering the "next generation" missile design.

DOT&E's proposal for early flight-testing with the new, "next-generation" missile has been integrated into the early developmental flight testing, first at White Sands--then at Kwajalein. The early flight testing is designed to demonstrate the capability of the new missile design to accurately intercept "threat representative" ballistic missile targets. Five successful intercepts are planned prior to the Department proceeding with the first limited production buy of the new missile design. The five intercepts will also provide critical data needed to validate the missile fly-out simulation for the redesigned missile. This approach provides an incentive for the contractor and Program Manager to conduct the necessary ground testing to ensure achieving the five intercepts with the minimum number of flight test attempts. The number of flight tests it takes to accomplish the five intercepts should provide a good indication of how well the new missile design is performing so that the Department can assess the risk of continuing with the program.

The contractor indicates that the "next-generation" missile will be significantly redesigned. Thus, THAAD will require a comprehensive EMD test program. The following test series must be successfully completed to support the Milestone III decision:

- The prime contractor should complete engineering design tests of the prototype components and sub-systems.
- The THAAD system should complete a thorough product assurance and test program.
- The THAAD system should complete a ground test program that verifies performance and reliability of major missile sub-systems and the integrated missile prior to flight tests.
- Prior to committing to the production design, the THAAD system should successfully complete the five intercepts in the early developmental flight tests in EMD to reduce risk.
- After production processes are relatively firm, the THAAD system should complete a robust flight test program that includes environmental testing and field exercises on the integrated THAAD system using trained soldiers.

The THAAD project office and contractor are planning for more robust ground testing and HWIL simulation on EMD missiles. Currently, the project office is considering a ground and HWIL simulation test program that will include:

- Qualification tests in which units are qualified to levels 6 Decibels over worst case expected flight vibration environments.
- Testing critical components to failure to demonstrate design margins.

- Shroud and kill vehicle/booster separation dynamics and effects testing.

- Short hot launch tests for the booster.

- MIL-STD 461 electromagnetic compatibility tests.

- Vibration, shock, and thermal tests.

- Pallet loading, rail transportation, and drop tests.

- Comprehensive Built-in-Test checks.

- Closed-loop simulated flight at the production facility.

DOT&E is also encouraging THAAD to perform extensive end-to-end HWIL including radar, missile, BMC^3I, and launcher components. End-to-end HWIL simulations should include maximum threat loading and high fidelity scene generation of the endgame. Additionally, the entire system should be subjected to extreme operating environments to ensure that the system performs anywhere it is deployed.

Problems with the PDRR missile were significant. Subsequent to a THAAD Critical Technical Review in June 1997, DOT&E formally identified to BMDO a number of problem areas including design, product quality/assurance, and testing which needed to be addressed further by the prime contractor. The issues resulted in the THAAD program suspending flight testing for 14 months after FT-07, while the missile design, pedigree, product assurance, and testing were reviewed by the contractor and an independent government team sponsored by the THAAD Program Manager. During this timeframe DOT&E, BMDO, and DTSE&E also co-sponsored the "Welch Panel" chaired by General Larry Welch (USAF Ret.) and comprised of senior experts from the public and private sectors. The Welch Panel conducted a comprehensive review of all BMDO acquisition programs for obvious problem areas and deemed the following factors as most relevant to explain the inadequate performance of the THAAD PD&RR system:

- The sense of urgency to deploy a UOES resulted in an overly optimistic development schedule. Rather than being event driven—proceeding in development only after technical milestones were met—the program was driven to keep pace with the planned schedule. Schedule forces and budget cuts contributed to deficient manufacturing processes, quality control, product assurance, and ground testing procedures which in turn resulted in poor design, lack of quality, and failed flight tests. The ultimate result, ironically, was a schedule slip of nine years. The Milestone III decision, initially scheduled in 1991 for FY00, is now expected no earlier than FY10.

- Quality control deficiencies in the manufacturing of the interceptor are a major factor in all but one of the flight test failures. As described above, FT-5, FT-6, FT-7, FT-8, and FT-9 failed because of some relatively low technology, manufacturing defects unrelated to the particular demands of hit-to-kill.

- The integration of high technology hit-to-kill TBM systems with common integration, assembly, test, and quality control processes has proven to be more difficult than previously anticipated. THAAD demonstrated the unique aspects of hit-to-kill technology and produced substantial amounts of in-flight environmental data during all phases of the engagement. These data, together with data collected during HWIL testing of the seeker, indicate that automated image processing performed during the endgame is likely to be a major challenge in the development of this technology.

During the 14-month delay following the FT-7 failure, the Program Manager and contractor conducted a thorough examination of its practices. Actions taken to improve pre-flight testing and quality control for all subsequent flight tests include:

- Complete pedigree review of hardware design and maturity at the component and sub-system level.
- More demanding environmental stress screening and flight certification testing.
- HWIL testing of the seeker at the U.S. Army's high fidelity scene generation facility in Huntsville, AL.

As a result of DOT&E's encouragement, the Program Manager agreed to test the FT-08 seeker in a high fidelity HWIL facility. This represented a significant advancement for the THAAD program. Notwithstanding the costs, schedule and hardware constraints faced by the program, pre-flight testing of the seeker was conducted at the Army's high fidelity HWIL facility for FT-08 and all remaining PD&RR flight tests. Nonetheless, even more comprehensive ground testing of the missile at the subsystem and system levels is needed since THAAD must engage targets across a wide envelope, most of which will not be demonstrated in open-air flight tests. DOT&E is currently working with the THAAD PM and BMDO to define an adequate pre-flight ground test program.

The original flight envelope for THAAD was extremely challenging since it required the THAAD missile to intercept targets flying both in the atmosphere and outside the atmosphere. As part of the missile redesign, the requirement for intercepts deep within the atmosphere is being relaxed. The required minimum engagement altitude for THAAD is still endoatmospheric but is raised higher than originally in the PDRR phase. Analyses conducted by the contractor, the PM and the User shows there is no degradation in the THAAD system against "threshold" ORD performance requirements. This means that THAAD must be fielded with a lower tier system (e.g. PAC-3) to provide the near leak-proof protection against all threats in the theater.

CONCLUSIONS, RECOMMENDATIONS, LESSONS LEARNED

DOT&E's early participation and influence in the PDRR phase of the THAAD program has directly contributed to more comprehensive pre-flight ground testing. The recent successes of THAAD, PATRIOT PAC-3, the Navy Area Program, and the National Missile Defense programs can be directly traced to robust pre-flight ground testing and analyses.

Stable program funding and guidance is essential for program success—especially for a program as complex as THAAD. Political pressures to quickly field a TBMD capability, budget cuts, and program restructuring combined with the freedom and flexibility allowed by acquisition reform, all strongly influenced the Program Manager and contractor to make the controversial programmatic decisions and tradeoffs with schedule as the leading priority.

Program execution must be event driven rather than schedule driven. Experience shows that event driven programs have the best opportunity of succeeding in the shortest time. The Welch Panel concluded that the THAAD program "rushed to failure" because the program was schedule driven.

The THAAD contractor must implement significantly improved component-level engineering design and qualification testing, quality control processes, and product assurance testing procedures in the development and manufacturing of the interceptor. Improved component-level quality testing that confirms both design and reliability will greatly increase confidence that the integrated missile will perform as intended.

The PM and contractor must perform, as planned, thorough ground and HWIL testing of the THAAD system, including system end-to-end testing.

The THAAD PD&RR missiles have not proven to be effective and reliable. Pursuing the PDRR design into EMD is not warranted given the PDRR flight test record, quality control problems, and known design deficiencies. Through hard work and perseverance during PD&RR phase of development, THAAD has proven that the hit-to-kill technology and the THAAD design are potentially effective against TBM missiles. Now, THAAD must revisit the design to increase its reliability, testability, producibility, and affordability.