AIRBORNE LASER (ABL)

Air Force ACAT ID Program

Total Number of Aircraft:	7
Total Program Cost (TY$):	$6,335M
Average Unit Cost (TY$):	$528M
Full-rate production:	FY08

Prime Contractor

Boeing

SYSTEM DESCRIPTION & CONTRIBUTION TO JOINT VISION 2020

The Airborne Laser (ABL) is intended to shoot down enemy Theater Ballistic Missiles (TBMs) during their powered boost phase of flight. The ABL engagement concept calls for the laser to focus on a distant missile's booster skin, rupturing it or damaging it sufficiently to cause the missile to lose thrust or cause a loss of flight control and fall short of its intended target. The ABL engagement of TBMs in the boost phase is intended to result in the negation of the missile before decoys, warheads, or submunitions are deployed.

The aircraft will be a modified Boeing 747-400F (freighter), carrying a megawatt-class Chemical Oxygen Iodine Laser operating in the near infrared (1.315 microns). In addition to the laser, the ABL system will also have a Beam-Control/Fire-Control (BC/FC) system and a Battle Management, Command, Control, Communications, Computers, and Intelligence (BM/C^{4}I) system. The BM/C^{4}I system will autonomously acquire the target and manage much of the engagement. After a target has been acquired, the BC/FC system will actively track the missile and use adaptive optics to compensate for the degrading effects of atmospheric turbulence on the laser beam's path. Once the BC/FC system has established a track, the high-energy laser will irradiate the missile until it has been negated.

ABL will be rapidly deployable and add a boost-phase layer to the Theater Missile Defense's (TMD) Family of Systems. It will be positioned behind the forward line of friendly troops and moved closer toward enemy airspace as local air superiority is attained. The Air Force is proposing a seven aircraft fleet, and envisions that five aircraft would deploy to support two 24-hour combat air patrols in a theater.

Theater missile defense is a central aspect of ***Joint Vision 2020***. ABL will utilize technological innovation to achieve ***precision engagement***. Operationally, it will provide ***full-dimensional protection*** of U.S. and friendly forces, cities, ports, airfields, and other infrastructure in the theater.

BACKGROUND INFORMATION

The technologies supporting ABL have evolved from more than 25 years of DoD and Air Force Research Laboratory (at Kirtland AFB, NM) work in the areas of laser power generation, pointing and tracking, and adaptive optics. In the early 1980s, the laboratory operated the Airborne Laser Laboratory, which successfully shot down five AIM-9 air-to-air missiles and a BQM-34 simulated cruise missile at White Sands Missile Range, NM. In addition, the Strategic Defense Initiative Organization (now the Ballistic Missile Defense Organization) funded a number of efforts relating to adaptive optics and beam control. These technology investments established the technical feasibility of the airborne laser concept.

In FY94, the Air Force launched a formal Airborne Laser program that awarded two separate concept design contracts to competing teams. The program passed Milestone I and entered the Program Definition and Risk Reduction (PDRR) phase in November 1996. The Air Force selected a single team from the two competing concept teams by awarding the contract to the team of Boeing (prime), TRW (laser), and Lockheed Martin (beam control).

During the PDRR phase, one ABL system will be built to demonstrate the feasibility of the system. The high-energy laser on the PDRR system will have about half the energy of the full production-representative system, and a number of the other subsystems will also not be production-representative. However, the PDRR phase—which will culminate with full-up flight tests against representative TBMs in FY03-04—will be an important step in validating the ABL concept and retiring critical areas of risk.

As the PDRR system is integrated, a series of ground and flight tests will be conducted that incrementally demonstrate capability. The PDRR test program is closely tied to the integration schedule of the PDRR system, with ground and flight test activities scheduled after each stage of segment integration. The segments of the PDRR system will be integrated in three major steps:

- Integration of the BM/C^{4}I on the aircraft.
- Integration of the Beam-Control and Fire-Control segment with the BM/C^{4}I and aircraft segments.

- Integration of the high-energy Chemical Oxygen Iodine Laser with other segments on the aircraft.

There are several interim milestones during PDRR. The program successfully passed the first Authority to Proceed (ATP-1) decision in summer 1998. This decision allowed the Air Force to commit to the purchase of the commercial 747-400F, which will be used for the PDRR system. The ATP-1 decision was based on: (1) demonstration of a lightweight laser module; (2) demonstration of active tracking; (3) characterization of atmospheric turbulence; and (4) demonstration of compensation and fine tracking.

As currently planned, an ATP-2 review is scheduled for late FY02. Current ATP-2 criteria are: (1) demonstrating performance of the integrated PDRR beam control system at low power; (2) laser scaling and multi-module operation of the PDRR laser modules; and (3) an integrated surveillance system performance. This review will authorize the long-lead purchase of the EMD aircraft.

The EMD phase is scheduled to begin in March 2004 and end two years later. During EMD, a full-power production-representative ABL system will be built and tested. Details of this phase are still being developed, but (as discussed in the Assessment section) this appears to be an inadequate amount of time planned for this phase of the program.

The ABL has experienced several budget cuts in recent years. A $25 million funding cut in FY99 caused a program restructure, resulting in the PDRR phase being lengthened by one year. Most other program dates (ATP-2, MSII, and MS III) were correspondingly delayed by a year. Early in FY00, a series of budget cuts totaling over $900 million between FY01-05 were proposed in the President's budget. Congress has restored most of FY01 funding, and the Air Force has committed to restore funds in FY02-03. Although this results in full funding for PDRR, a shortfall remains for the EMD phase slated to begin in FY04.

During FY00, the engineering and design of the ABL system progressed according to schedule. The program took delivery of the PDRR aircraft from Boeing's commercial assembly line in January, and modifications began that same month at Boeing's Wichita plant. A system-level critical design review was held in April 2000.

TEST & EVALUATION ACTIVITY

Revision of the TEMP continued during this period, documenting changes made to the program as a result of budget cuts and program restructure. The System Program Office has committed to finish this update and submit it to OSD in early FY01.

The program has been actively collecting data to address one of the most challenging issues facing the ABL—atmospheric turbulence. Atmospheric data have been collected in Korea and Southwest Asia over four seasons for several years using several different techniques; e.g., balloons and aerothermal probes. One issue has been correlating the data made with these different techniques, and converting these measurements to path-integrated values of turbulence relevant to ABL engagements. In FY00, a stellar scintillometer was used to measure turbulence in these theaters, with the intent to provide a more direct measure of path-integrated turbulence and correlate the measurements taken with other techniques.

Early in PDRR, tracking and compensation demonstrations in support of ATP-1 were conducted at White Sands Missile Range and at MIT Lincoln Laboratory's Firepond facility. More recently, additional tracking and compensation tests were conducted at White Sands' North Oscura Peak. The ranges at North Oscura Peak are longer (~50 km) than in the previous tests (~5 km), and the path-integrated turbulence levels should be more representative of ABL engagements. Dynamic cooperative tests were completed in 3QFY99, and dynamic, non-cooperative tests were done in 2QFY00.

Laser development and testing has continued, and contributed to the final laser-module design available for testing in 3QFY01. Several other development and test phases are planned during PDRR, leading up to the mature PDRR and EMD laser designs.

Another area of ongoing test activity involves lethality mechanisms. Several experiments have been conducted by the Air Force Research Laboratory to measure fundamental thermodynamic and optical properties of relevant materials, including some countermeasure candidates. These measurements include high temperature properties and the response of materials to laser radiation. To gain a better understanding of the internal operating condition of an in-flight missile, critical components and sub-systems have been investigated under simulated flight and propulsive conditions.

TEST & EVALUATION ASSESSMENT

The ABL is a completely new type of weapon system. Besides presenting a challenging set of engineering issues to the contractors, the ABL also presents a new set of challenges in conducting adequate operational test and evaluation. The ABL will be a very complex system, and will have many state-of-the-art systems; e.g., gas lasers and optics that normally exist in laboratory environments rather than in operational, flying military systems. Thus, a very thorough evaluation of operational effectiveness and suitability must be conducted to ensure that the ABL can perform its mission and be safely maintained in the operational environment with acceptable levels of readiness.

The test activities planned for PDRR should address the fundamental ABL issues of atmospheric turbulence and compensation, lethality, laser development, and integrated system performance. Testing should adequately demonstrate, in a logical progression, individual segment performance as well as increased capability and the ability of the segments to operate together as an integrated system. Overall, the PDRR program contains reasonable amounts and types of tests, but the schedule is ambitious and clearly success-oriented.

An even more ambitious schedule is envisioned for the EMD phase: 24 months to fully integrate and operationally test a production-representative ABL. The abbreviated EMD phase was originally justified by assuming that the PDRR and EMD systems would be identical, except for the number of laser modules. However, the PDRR and EMD designs are beginning to differ more significantly, and this is no longer a valid approach. The current EMD plan also results in a high degree of concurrency between the PDRR and EMD phases, which increases risk and may not provide adequate time to transfer lessons learned during PDRR testing into the EMD design. Furthermore, when compared to other major acquisition programs that are less complex, the 24-month EMD program is alarmingly short. We believe that the proposed EMD schedule for ABL, a high-technical risk program, allows for no technical problems or test failures, and the many integration and test activities cannot all physically be accomplished in the time allotted for EMD.

There will be significant challenges involved in adequately testing and evaluating ABL against an appropriate cross-section of its intended targets. Specific concerns include the following:

- The ABL STAR lists approximately 30 threats that the ABL is required to negate. These missiles include a diverse range of operating characteristics, including liquid and solid-fueled, single and multi-stage, and metal and composite body missiles. There may be other important lethality considerations among these missiles, and the missiles may also have different range and dynamic characteristics. However, it is unlikely that more than one or two of these missiles will be available for actual ABL testing, and it is unclear how the program intends to demonstrate effectiveness against the array of different missile types.

- The ABL ORD specifies minimum and maximum values of range, azimuth angle, and elevation angles for ABL engagements. Besides these parameters, the level of atmospheric turbulence will have an important effect on ABL's effectiveness. Other variables that may be important include whether the engagement is conducted during the day or at night, and the presence of clouds. However, it may be difficult to perform end-to-end operational tests that cover all of the important areas of this parameter space. Although the ABL's operational requirements are based on a turbulence level of "one times clear 1 night" (a measure of turbulence strength), the results of the atmospheric data collected to date indicate that this turbulence level will occur only 50 percent of the time. In contrast, 80 percent of the expected conditions fall within the turbulence level "two times clear 1 night." These results will be used to shape ABL's OT&E program.

- Based on the threats, range, and geometry, there will also be a set of dynamic conditions that the ABL encounters during an engagement. This parameter space may also have important effects on ABL performance, but at a more fundamental level. For example, the exact location of where the high-energy laser is aimed may have an important effect on lethality. The ability of the ABL to correctly identify the type of TBM and determine the optimal location to place this beam may depend on the dynamics and geometry of the engagement, and should thus be evaluated across the breadth of threat missiles and engagement conditions. An additional challenge will be the evaluation of ABL's effectiveness against salvos, or multiple, near simultaneous launches.

Other key test issues include:

- Countermeasures may be employed to reduce ABL's effectiveness. Likely candidates need to be identified and included in ABL's test program.

- As mentioned above, producing a system that is operationally suitable will be a challenge. The ABL system may have new and unique maintenance requirements compared to other airborne military systems. Thus, adequately assessing the reliability, maintainability, availability, safety, and the required logistics support of the ABL in operationally realistic conditions should be an important part of OT&E.

- In the ABL ORD, a successful negation occurs if the thrust of the missile is terminated by the ABL at a specified time before it would have normally terminated. This will cause the missile to fall short of its intended target. However, since the ABL may not catastrophically destroy the missile, there is a chance that the warhead(s) could still cause damage. Also, when the thrust termination requirement was developed, some assumptions were made regarding the remainder of the missile's flight path. These assumptions should be verified during the test program, as well as assessing the warhead behavior after an ABL engagement. Again, these evaluations should be performed across the breadth of targets documented in the STAR.

- The exit criteria for Milestone II need to be resolved soon to allow advance planning. One of the most important of these criteria concerns the number of threat representative end-to-end missile negations required before Milestone II. This criterion was modified early in FY00 at the Integrating IPT level from one to three missile negations. However, more detailed planning of the test scenarios and conditions have stalled awaiting convening of an OIPT to ratify this change. Because of the importance and visibility of these demonstrations, we encourage the planning of these tests to begin as soon as possible.