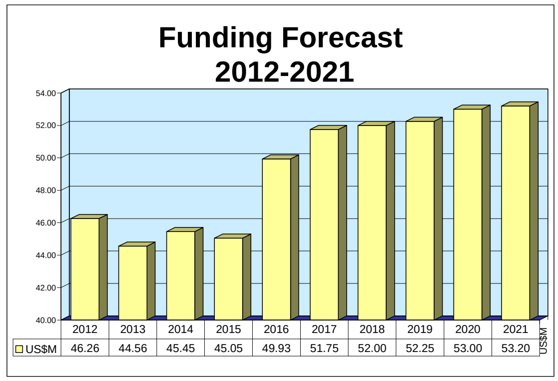
Airborne Laser (YAL-1A)

Outlook

- The U.S. MDA is refocusing its research efforts into alternative directed-energy ballistic missile defense systems
- The Airborne Laser Testbed (ALTB) and Airborne Laser (ABL) were retired in 2012
- ABL funding ended with FY12; RDT&E funding from 2013 on is to develop Diode Pumped Alkali Laser Systems (DPALS) and fiber combining laser technologies



Orientation

Description. The Airborne Laser (ABL) program funded the development of an airborne chemical oxygen-iodine laser (COIL) with an air-based boost missile defense capability to equip a modified Boeing 747-400F, dubbed the YAL-1A. The Airborne Laser Testbed (ALTB) is a science and technology platform for high-power laser research.

Sponsor

Missile Defense Agency (MDA)
7100 Defense Pentagon
Washington, DC 20301-7100
USA
Tel: + 1 (703) 697-8472
Web site: http://www.mda.mil

Status. The ALTB and the ABL have been decommissioned. Further directed-energy ballistic missile defense research is being pursued.

Application. Ballistic missile defense – boost-phase intercept of attacking ballistic missiles. The airborne laser is mounted on a modified Boeing 747-400F. The ALTB is a test bed for high-power laser research and experimentation with new hardware.

Price Range. According to the U.S. MDA, the prototype aircraft used in February 2001 tests has a $5 billion-plus price tag.

Contractors

Prime

Boeing	http://www.boeing.com, 100 N Riverside, Chicago, IL 60606 United States, Tel: + 1 (312) 544-2000, Fax: + 1 (312) 544-2082, Prime
Lockheed Martin Space Systems - Sunnyvale	http://www.lockheedmartin.com/ssc, 1111 Lockheed Martin Way, Sunnyvale, CA 94088-3504 United States, Tel: + 1 (408) 742-4321, Co-producer
Northrop Grumman Aerospace Systems, Space Systems	http://www.as.northropgrumman.com, 1 Space Park, Redondo Beach, CA 90278 United States, Tel: + 1 (310) 812-4321, Fax: + 1 (310) 813-7548, Co-producer

Comprehensive information on Contractors can be found in Forecast International's "International Contractors" series. For a detailed description,

Technical Data

Design Features. The Airborne Laser (ABL) program was created to design, build, and test a laser weapon system that can acquire, track, and kill theater ballistic missiles (TBMs) in their boost phase. This weapon system would integrate three major subsystems (laser; beam control; and battle management command, control, communications, computers, and intelligence [BMC^4I]) on a modified Boeing 747-400F aircraft. It would also offer ABL-specific ground support. The laser itself would consist of a 1- to 2-MW chemical oxygen-iodine laser (COIL) and an accurately stabilized optical mount with a 3- to 4-foot-aperture diameter.

The active-ranger several-hundred-watt CO_2 laser propagates at 11.5 microns and identifies a missile's general location, speed, and trajectory. The track illuminator laser is a solid-state, pulsed laser that propagates at 1.03 microns and has the job of scanning the target missile from nose to plume and pinpointing the location of the fuel tank. The solid-state pulsed beacon illuminator laser operates at 1.06 microns and measures atmospheric disturbance. The megawatt-class COIL is to be powered by six modules and will provide the missile-destroying beam.

A major technical challenge for ABL is the long movement path through the atmosphere, which causes distortion of the high-energy laser beam. These atmospheric effects were measured by the Air Force as part of its ABL risk-reduction program. Lockheed Martin used this measurement data to anchor its beam control laboratory demonstrator and high-fidelity optical simulations. The data were also used to fabricate atmospheric turbulence simulation optics, or "phase screens," which permitted the beam control system design to be reproduced and evaluated. The anchored high-fidelity simulation software code would be used to evaluate those ABL engagement scenarios that cannot be easily tested in the laboratory.

Operational Characteristics. The operational concept envisions an airborne Attack Laser aircraft flying over friendly territory roughly 90 kilometers behind the front line at altitudes above 40,000 feet, in a figure-eight pattern. Once air superiority is achieved, the system will move to a more forward operating location. Through in-flight refueling and rotation of aircraft, two ABLs could always be on patrol, ensuring 24-hour coverage of potential missile launch sites within the theater of operations.

The ABL is expected to operate from a central base in the United States and deploy worldwide as needed. The program calls for a seven-aircraft fleet, with five available for operational duty at any given time. The other two aircraft would be undergoing modifications or maintenance and repair. When on patrol, the ABLs would receive fighter or surface-to-air missile protection, as do other high-value air assets such as AWACS and JSTARS.

Once a missile is fired, it takes up to 40 seconds to clear cloud cover before an infrared sensor on the ABL aircraft detects the rocket plume. The system then has a 60- to 300-second window in which to illuminate the rocket body with a low-power tracking laser so the system can adjust for atmospheric perturbations. It then fires a high-powered COIL that heats up the rocket body to the point that internal pressure breaks the missile's skin. A nominal 5-second dwell on a rocket will theoretically destroy it, with a range of hundreds of kilometers considered possible, depending on the target. The engagement will conclude at altitudes of 20 to 450 kilometers.

The aircraft would be equipped with a 360º field-of-view infrared sensor to provide autonomous detection, acquisition, tracking, and targeting without external cueing. The aircraft is envisioned to be capable of engagements at ranges to 600 kilometers (375 mi) and to carry sufficient laser chemical fuel for 30 to 40 engagements during a 12- to 18-hour mission.

The original plan was for the fleet to satisfy the Air Combat Command's boost-phase missile air defense requirements as part of a "tiered architecture" of defenses. The program has been changed to the Boost-Phase Missile Defense Segment, with some requirements being updated.

Variants/Upgrades

The program has a spiral development plan. Each spiral is a separate block.

Block 2004 is the first increment in the spiral development of an air-based, boost-phase intercept capability using direct energy. This first ABL weapon system testbed under development in Block 2004 represents a unique, dedicated, highly mobile weapon element for the overall ballistic missile defense system (BMDS). In addition to a boost-phase defense weapon, the ABL adds a sensor element.

Block 2006 will enhance BMDS integration and ground support. Block 2006 will be marked by studies on the requirements for the baseline of an optimal second ABL aircraft to further guide other efforts and reduce risk and uncertainty.

Block 2008 furthers ground and flight testing of the first ABL weapon system, and includes evaluations against a broader spectrum of threats. The Block 2008 program continues ABL-specific technology and infrastructure improvement efforts as well as work to define the second ABL aircraft.

Block 2010 addresses a broader range of threats and works toward integration with an overall BMDS. It focuses on the second ABL testbed, addressing performance enhancements and life-cycle cost considerations. It moves the program from design and development to acquisition and deployment.

Airborne Laser Test Bed (ALTB)

Source: Missile Defense Agency

Program Review

In 1994, the United States Air Force awarded separate contracts to teams headed by Boeing and Rockwell International to perform the first of a two-phase concept validation program to demonstrate technologies to acquire, track, and kill theater ballistic missiles in the boost phase from an airborne platform.

The contracts, valued at approximately $21 million each, were for a Phase I conceptual design effort. The teams were expected to develop a conceptual and demonstrator design, conduct demonstrations and simulations to reduce technical risk, and address cruise missile defense and protection of high-value assets.

In 1996, the Air Force awarded a $1.1 billion contract to Boeing for Program Definition and Risk Reduction (PDRR). Under a cost-plus-award-fee contract, Boeing would produce the YAL-1A prototype aircraft using a commercial 747-400F airframe.

Airborne Laser (YAL-1A)

Boeing teamed with TRW Space and Electronics Group (now Northrop Grumman) to develop the laser, and Lockheed Martin to build the beam and fire control system. Boeing would manage systems integration, aircraft modifications, and the development of battle management computer and software systems.

In 1998, a high-energy ABL module was successfully operated. The flight-weighted module was a multi-hundred-kilowatt-class chemical oxygen-iodine laser (COIL). This was the beginning of a series of laser performance tests dedicated to reducing the program's technical risk. The flight-weighted laser module produced 10 percent "beyond-the-design" power output. The performance and fieldability of the COIL were improved, and it was transitioned to the airborne laser system acquisition program.

Corning Glass produced the primary optical mirror that will focus the laser beam on the target. It is 62 inches in diameter and 8 inches thick, and fits in the turret ball on the nose of the aircraft. A special manufacturing process resulted in a lighter (330-pound) mirror with superior performance compared to solid mirrors, which weigh nearly 2,000 pounds.

Program Restructured

A $25 million cut in the FY99 budget made it necessary to restructure the program and move the first live-fire test from 2002 to 2003. Six months were added to the test program so the ABL could shoot at more targets. Originally, designers were to test the beam control and laser on the ground and then integrate them onto the 747. These efforts were instead split up to reduce risk. First, the battle management system would be tested on the aircraft, followed by the beam control and then the laser. Although the program was considered to be moving along well, many of the risk-reduction efforts were to alleviate concerns on Capitol Hill.

In 1999, a scaled laser was fired at the White Sands Missile Range, replicating the engagement of a target at 300 to 400 kilometers, using a scaled laser and functional equivalent of the ABL beam control system. The system put sufficient energy on target, even though atmospheric conditions were considered three times worse than those in which the ABL is expected to operate. Tests against an instrumented aircraft, the equivalent of a 300-kilometer Scud missile, delivered 70 percent of the laser's output energy on the target. Other tests showed that the system was exceeding the established range requirement.

GAO Questions Tests

In mid-1999, the Government Accountability Office (GAO) recommended that the procurement of a second aircraft be delayed until after the first intercept attempt. Congressional critics also questioned the Air Force's selection of a COIL, stating that a solid-state laser might be more effective.

Boeing began assembly of the first aircraft in August 1999. During the summer, a flight-weighted laser module generated 107 percent of the required ABL power in laboratory tests. The laser also ran 15+ seconds in an endurance test. In December 1999, the Air Force certified to Congress that the ABL program was proceeding as planned and that engineers could start to modify the first 747-400 into a YAL-1A.

In April 2000, the Air Force and Boeing successfully completed the Critical Design Review, clearing the way for the first test with the laser mounted in an aircraft. Modifications to the first aircraft began, including installing the 11,500-pound, two-axis nose turret and super-strong structure components needed for the 36 exhaust ports that would be drilled through the skin. A special floating pressure bulkhead would protect the crew from the laser equipment and chemicals.

First Test Flight in 2002

The first test flight of the modified aircraft took place in July 2002. After flight tests, the aircraft was moved to Edwards AFB for installation of the tracking and high-energy laser systems. In August, it successfully detected and tracked a Lance target missile. The Beacon Illuminator Laser (BILL) was delivered in early 2003.

But the program began to have troubles in 2003. Increasing expenses forced the USAF to add $242 million to the program. At the same time, the American Physical Society (APS) stated that the system would not be effective against solid-fueled rockets, which, they added, are becoming increasingly common in world inventories. The U.S. Air Force also decided to equip the aircraft with only six COIL modules instead of the originally intended 14, because the weight was much higher than originally envisioned.

In August 2003, MDA officials announced they would use a Boeing 747-400 freighter for the second aircraft, not the passenger airframe that had been under consideration. The freighter could better accommodate the battle management suite on its upper deck.

In January 2004, officials mixed a 1,200-gallon batch of chemicals for the COIL. This was considered the first step in firing the laser, one of the most challenging systems in the ABL's development.

In early 2004, Lockheed Martin tested the optical benches for the multibeam illuminator and beam transfer assembly. These are the two major elements of the ABL's beam control/fire control system.

In May 2005, the ABL's 1.7-meter-wide conformal window was unstowed for the first time during flight, a maneuver necessary for the weapon system to shoot down a ballistic missile inflight. The team also demonstrated the system's ability to autonomously detect and hand off targets using Link 16 secure communications. The system also completed flight testing of the passive mission payload. After these tests, the YAL-1A aircraft was sent to Boeing's Wichita facility to undergo final modification to accommodate installation of the high-energy lasers and begin Low Power System Integration-Active ground testing.

A major milestone was reached in July 2006 when the ABL system tracked and targeted a simulated ballistic missile in boost phase in ground tests.

First ABL Rolled Out of Plant

The first ABL aircraft was rolled out in October 2006. While in Wichita, Boeing, along with Northrop Grumman and Lockheed Martin, integrated the beam control/fire control system. The team also added floor reinforcements and chemical fuel tanks to prepare for the installation of the laser. The aircraft then returned to Edwards AFB for long-term testing.

Program Threatened by Congress

Congress has repeatedly threatened to cut funding from the ABL program as part of a wider debate over missile defense. For FY08, the House proposed cutting funding to $300 million, while the Senate proposed cutting it to $350 million. However, after intense lobbying efforts by industry and Air Force officials, only $35 million was cut from the FY08 budget.

2007-2008 Milestones

In March 2007, engineers successfully fired the ABL tracking laser at an airborne target for the first time in flight. During the test, the aircraft used infrared sensors to find the simulated ballistic missile exhaust. The aircraft then pointed and fired its track illuminator laser (TILL) at the target to gather target-tracking data. The TILL, a solid-state laser, is part of the beam control/fire control system.

In May, passive sensors located, acquired, targeted, and tracked an F-15 jet. During flight tests, the TILL fired 50 times for up to 90 seconds at a time. Also in 2007, Northrop Grumman completed installation of the six high-energy COIL modules.

The ABL program reached a number of milestones in 2008. The program completed the first laser activation testing on the ground in May, which ensures that each subsystem can be brought on-line sequentially and safely. The installation of the laser on the aircraft was also completed, and engineers began testing with the chemical fuel. By September 2008, the laser had successfully fired in ground testing – it was fired for less than a second each time.

2009-Major Blow

The ABL program received a major blow in April 2009, when Secretary of Defense Robert Gates announced that the Pentagon canceled the building of a second ABL aircraft. In addition, the program is no longer funded as a technology demonstration program. Instead, it has been reclassified as an R&D program, and will focus on laser research.

Anticlimax – New Milestones

In June 2009, the ABL tracked a non-instrumented boosting missile in flight with lasers that were able to compensate for atmospheric conditions and remain locked on the missile for an extended period. In August, engineers completed the ABL's first in-flight test against an instrumented target missile. During the test, the aircraft used its IR sensors to find a target missile launched from San Nicholas Island, California. The ABL battle management system issued engagement and target location instructions to the beam control/fire control system, which acquired the target and fired its two illuminator lasers to track the target and measure atmospheric conditions. The same month, engineers successfully fired the high-energy (COIL) laser in flight for the first time.

2010 Ballistic Missile Shootdown

The MDA announced in February 2010 that the Airborne Laser Testbed (ALTB) successfully destroyed a boosting ballistic missile.

The MDA disclosed that on February 11, a short-range, threat-representative liquid-fueled ballistic missile was launched from an at-sea mobile launch platform. The ALTB used onboard sensors to detect the boosting missile, a low-energy laser tracked the target, and a second low-energy laser calculated the compensation for atmospheric disturbance. Finally, the ALTB fired its megawatt-class High Energy Laser, heating the boosting ballistic missile to critical structural failure. The entire engagement occurred within two minutes of the target missile launch.

Airborne Laser (YAL-1A)

Funding

U.S. FUNDING

	FY11 ACT	FY12 ACT	FY13 EST	FY14 EST	FY15 EST	FY16 EST	FY17 EST
RDT&E (U.S. Missile Defense Agency)							
PE#0603901C Directed Energy Research							
MD69: Directed Energy Research	122.8	46.3	44.6	45.5	45.0	49.9	51.7

All $ are in millions.

Source: U.S. FY13 President's Budget, Missile Defense Agency, Justification Book Volume 2a, RDT&E–Defense-Wide, Feb 2012.

Contracts/Orders & Options

Contractors	Award ($ millions)	Date/Description
Boeing	500.0	Apr 2003 – ID/IQ CPAF contract increment of $190 million (not to exceed $500 million) to deliver an Iron Bird testbed in support of the ABL. The testbed will be located at Edwards AFB, CA. Period of performance is Apr 2003 through Apr 2013. The intent is to develop a permanent ground test facility that can be used to troubleshoot the ABL, conduct advanced-technology evaluation/validation, integrate representative ABL subsystems, simulate the fully integrated ABL weapon system, host Block 2002 laser module testing, support integrated BMDS testing, wargaming, and conduct lethality testing. (F33657-03-D-2036)
Boeing	118.5	Apr 2003 – CPAF contract in support of ABL Block 2008. Period of performance is Apr 2003 through Mar 2004. The not-to-exceed contract encompassed an 11-month design effort leading to a successful System Design Review. Delivered under the contract were a system specification with draft segment specifications, evidence of performance, functional design and process analyses for requirements and affordability, and documentation of plans and processes, along with recommendations for technology integration. (F33657-03-C-0001)
Boeing	241.8	Jul 2003 – CPAF mod to contract for the ABL 2004 effort. The modification accounted for cost adjustments for the laser, beam control, and integration and test efforts. In addition, this mod removed CLIN 0006, Block 2008 aircraft, which will be procured under a separate contract. Completed Jun 2005. (F29601-97-C-0001)
Northrop Grumman	142.0	Jan 2005 – ID/IQ CPAF contract to provide technical and engineering support to the Airborne Laser and Airborne Sensor programs. (FA8632-05-D-2453)

Timetable

Month	Year	Major Development
May	1994	Dual Phase I contracts awarded to competing Boeing and Rockwell teams
2Q	FY96	PDRR RFP release
3Q	FY96	Concept Design Review 2
1Q	FY97	PDRR contract awarded, flight-weighted laser module demo
2Q	FY97	Concept design, Program Requirements Review completed
3Q	FY98	Preliminary Design Review, order for PDRR "green" aircraft, flight-weighted laser module demo
Jan	1998	Nose turret and laser exhaust wind tunnel tests

Month	Year	Major Development
Jun	1998	Flight-weighted laser "first light"
1Q	FY99	Beam control processor demonstration
2Q	FY99	Laser module airworthiness and scaling demonstrations, Critical Design Review
3Q	FY99	North Obscura Peak integration and testing begun
3Q-4Q	FY99	Star scintillometer tests (CONUS)
1Q-3Q	FY00	Star scintillometer tests (Theater)
2Q	FY00	Green aircraft delivered to Wichita
3Q	FY00	North Obscura Peak integration and testing completed, CDR
3Q	FY01	Turret window fabrication completed
4Q	FY01	Laser module airworthiness demonstration
Oct	2001	Program transferred to Missile Defense Agency
Jul	2002	First flight of YAL-1A
1Q	FY03	Illuminator performance and laser/structural weight reduction efforts initiated; contract for second ABL awarded; flight test on Proteus aircraft
3Q	FY03	Start of low-power missile target flight test
4Q	FY04	Start of integration of BCFC into first ABL
Nov	2004	Six-module laser test
Dec	2004	Initial beam/fire control flight test
1Q	FY05	First flight with BCFC system
3Q	FY05	Link 16 tests completed
4Q	FY05	Passive LP system readiness and flight tests
1Q	FY06	Laser module tests in Laser System Integration Laboratory completed
3Q	FY06	Tracking illuminator laser and beacon illuminator laser integrated on aircraft
4Q	FY06	Low-power active ground test completed; "laser provisioning" completed
1Q	FY07	Laser optics subsystem refurbished
2Q	FY07	Low-power active system integration and testing completed
2Q-4Q	FY07	Laser installation on aircraft, residual provisioning and modification, BCFC upgrades
1Q-4Q	FY08-11	Ground and flight tests
3Q	FY08	System ground tests completed
Apr	2009	Sec Gates cancels building of second ABL aircraft
Feb	2010	Ballistic Missile Shootdown
	2010	ABL/ALTB reclassified as a Research & Development program
Dec	2011	Confirmation that the ABL program will be shut down
Feb	2012	Final ferry flight of the ALTB

Worldwide Distribution/Inventories

This is a **U.S.**-only program.

Forecast Rationale

In December 2011, U.S. Missile Defense Agency (MDA) director, Lt. Gen. Patrick O'Reilly, notified the press that the Airborne Laser (ABL) program was soon ending. Over $5 billion in investment had been funneled into the ABL since the program began nearly 16 years previously.

On February 14, 2012, the YAL-1A Airborne Laser Test Bed (ALTB) took to the skies for its final ferry flight. Once the aircraft landed at Davis-Monthan AFB, Arizona, the ALTB was put into storage at the Air Force's Aerospace Maintenance and Regeneration Group. The aircraft is being preserved to protect its intellectual capital for possible use in future directed-energy programs.

MDA's Future in Directed-Energy Defense

While the ALTB is being retired and the YAL-1A ABL has reached the end of its life in its current incarnation, the MDA has continued interest in directed-energy defense systems. To further these technologies, the MDA is continuing to pursue the development of lasers for use in ballistic missile defense. Funding will continue under MDA RDT&E PE#0603901C, Directed Energy Research.

Airborne Laser (YAL-1A)

FY12 will be a transition year, as the decommissioning of the ALTB progresses and its research results are archived. For FY13 and beyond, the MDA will be channeling its research funds into national laboratories, federally funded research and development centers, and university applied research centers. Its goal is to mature both Diode Pumped Alkali Laser Systems (DPALS) and fiber combining laser technologies. A scaled, 200-kilowatt class prototype will be built and tested using the selected technology. This is reflected in the forecast figures.

The MDA will be developing a high altitude, long endurance (HALE) UAV as a suitable platform to collect environmental data beginning in FY12.

Ten-Year Outlook

ESTIMATED CALENDAR YEAR RDT&E FUNDING (in millions $)												
Designation or Program		**High Confidence**				**Good Confidence**			**Speculative**			
	Thru 2011	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**Total**
Boeing (Prime)												
Airborne Laser (ABL) <> United States <> Missile Defense Agency <> 747 -400 F												
	5176.71	46.26	.00	.00	.00	.00	.00	.00	.00	.00	.00	46.26
United States Government (Prime)												
Directed Energy Research <> United States <> Missile Defense Agency												
	.00	.00	44.56	45.45	45.05	49.93	51.75	52.00	52.25	53.00	53.20	447.19
Total	5,176.71	46.26	44.56	45.45	45.05	49.93	51.75	52.00	52.25	53.00	53.20	493.45