Airborne laser *aims at final tests*

Killing missiles at the speed of light, a capability long heralded in science fiction, may soon find practical application in the form of the airborne laser. After several delays, the technology has overcome some barriers once considered insurmountable, achieving major advances in power and performance. If upcoming tests are successful, the system could see deployment as early as next year. The greatest challenge, however, may be securing sufficient funding to keep the program alive.

by J.R. Wilson
Contributing writer

The idea of using a beam of light to shoot down an enemy platform has been part of popular fiction since before the first Buck Rogers story was published 80 years ago. More than three decades later, the concept began to draw real-world military interest with the invention of a device capable of light amplification by stimulated emission of radiation—the laser.

For the remainder of the 20th century, however, laser beams were either too weak to neutralize a missile or aircraft at any tactical distance, or too large and heavy, in concert with a power source, for practical use aboard an aircraft. But new, smaller, lighter, and more powerful devices began coming out of the labs just as computers evolved sufficient power and speed to handle the complexities of acquiring a target in flight and fixing the aim-point long enough to produce lethal damage.

The airborne laser (ABL) was the first serious attempt to design, build, demonstrate, and deploy a high-energy laser device—specifically, a chemical oxygen iodine laser (COIL) carried aboard a Boeing 747-400F freighter, described as the most heavily modified 747 in the world. The program began with a definition and risk reduction contract award to Boeing by the Air Force in 1996. Since being transferred to the Missile Defense Agency in October 2001 and converted to capability-based acquisition, the ABL has undergone dozens of tests, including ground tests of the laser and flight tests of the beam control/fire control system, in preparation for full system flight tests scheduled for this year.

Boeing, the team leader, is responsible for weapon system integration, the 747-400F aircraft, and BMC4I (battle management, command, control, communications, computers, and intelligence). Northrop Grumman designed and developed the COIL and the beacon illuminator laser, while Lockheed Martin supplies the beam control/fire control system.

The first attempt to shoot down a live missile of the type ABL would likely confront in actual combat is currently scheduled for August or September. The exact target remains classified, but program officials have identified it as a "foreign missile asset."

In one series of flight tests, the beam control/fire control system, mounted in the nose of the 747, engaged a Boeing NKC-135 "Big Crow" test aircraft. Lessons learned from the resulting data were parsed throughout 2008 in preparation for this year's tests, in which the full-scale COIL will use the system to fire outside the aircraft while in flight.

Air Force photo by Jim Shryne.

"We learned there were some jitter forces we had not anticipated in our system, although we arguably have one of the best jitter mitigation programs in the world," Boeing Missile Defense Systems vice president and ABL program director Michael Rinn tells *Aerospace America*. "We've put in dampeners to knock down those frequencies and now expect even more big things from the beam control system.

"On the high-power laser in back, we ran it in the system integration lab at Edwards [AFB] in 2005 and got a lot of lessons learned from that—some material, some mechanical and fluid timing. We rolled those into the laser design with Northrop Grumman, reintegrating all that laser hardware into the flight aircraft and firing it up to high power. We now appear to have a very bright, very powerful laser, although we still have a little fine-tuning to do—very minute, small adjustments in chlorine iodine and some of the key flows in the COIL—before we lock it down for the next flights."

Delays and cautious optimism

Despite a series of successes in the past two years, however, Rinn remains cautious, noting that significant technology, engineering, and funding challenges have plagued the program repeatedly since its inception. These have led to dramatic changes in the schedule, which has run longer than originally expected.

"If you go back to the beginning, ABL had to deal with a number of issues, both internal and external, which was not such a good story, but not unusual in terms of transitional technologies. The early predictions called for the first shoot-down in 2001-2003, so we're five or six years off that. But if you look at the schedule laid down five years ago, we're pretty close. And the amount of schedule slippage has definitely gone down in the last two years," he says.

Big Crow No. 38050 is one of two identically named NC-135Es, based at Kirtland AFB, that served as a surrogate target for the ABL's two illuminator lasers.

"During the low-power series of missions, we finished about three months late from where I really wanted to be. That's pretty good in this business, but not good enough. On the other parts of the program, however, I've gained back more than half that in the past year, so I'm still well within my window of what we promised our customer—in fact, a little ahead. But I'm driving my team to a much harder schedule to have some margin to deal with unknown unknowns. We do have some hard stuff in front of us."

A Northrop Grumman laser technician checks the fittings of a redesigned pump responsible for pumping chemical laser reactants through the ABL modules (top); then technicians double-check procedures for integrating and testing the first flight laser module.

Col. Robert McMurry, MDA program director, believes the successful ground and flight tests of 2007-2008 have proven the technology is now mature enough to take to the next level: killing a real missile in boost-phase flight.

"We are still on track for the missile shootdown demonstration in mid-2009, although there are a lot of first-time testings we have to do between now and that demonstration, so we could have some unknown events pop up. But as of now, the schedule still has that in August, and we're tracking toward it. We just have a lot of things to prove between now and then," he says.

"In the long history of the program, it is disingenuous to say we are tracking to the original schedule—ABL clearly is taking longer than originally expected. But we moved to a knowledge point in 2004-2005 and have made all our milestone commitments since that date," McMurry continues.

Thus ABL entered this year with all its systems having successfully completed individual tests, on the ground and in flight. Now they are being married for the first time in the 747 platform and gearing up to hit a real boosting missile—at full power—rather than the outline of one painted on the side of a comparatively slow-moving test aircraft target.

Testing sequence

"The sequence of testing, roughly, is repeating low-power tests to show we can do the acquisition-track-illuminate sequence we finished in 2007 as a kind of regression test. We'll also fire the laser again, not exiting the airplane, for a short-duration test in-flight, says McMurry. "Then we will propagate through the beam train into empty space, purposely firing at nothing, to make sure we see no stray lines or odd issues. At that point, the target program comes in, and we will launch and shoot against three different types of targets. The first is designed to check out the low power—what we did against the aircraft target—but now against an instrumented boosting target to see how we are keeping the spot on target.

"We will fire the high-energy laser against a Terrier Lynx missile, uninstrumented, then against an instrumented target—a MARTI (missile alternative range target instrumentation)—and measure how much energy hits the target. All that builds us up to confidence we are ready to fire against a demonstration target and shoot it down."

The MARTI target has a cylindrical body with holes in it, behind which are detectors to measure the laser energy that hits it. That information is quickly downlinked through the range instrumentation to show how much energy has been effectively put on the target. A very quick downlink is required so the target instruments are not destroyed before sending their data. Both tests will involve ground-fired boosted ballistic flight missiles with approximately the same body size as the short-range classified shootdown target missile.

That process, Rinn adds, has been laid out in great detail, incorporating all of the lessons learned to date.

"We start with safety of flight stuff, then we'll load some inert chemicals in the laser to make sure it's all tight and holding together, as it did quite well on the ground. After that come some low-power lasing tests using a new target—a Gulfstream with the profile of a foreign missile asset painted on it—to show we can find it and do atmospheric compensation," he says.

"Then we load real chemicals and fire the laser, first internally in the airplane, at a calorimeter—a device made out of copper plates that traps the light from the laser and turns it into thermal. You can only fire so long before you start melting it, but it allows us to bring the laser up without worrying about the beam going out of the aircraft. The next step is firing the laser end-to-end in flight. We won't aim for a target, just make sure the beam is aligned and the safety systems are working.

"Then we are ready to engage our first rockets, beginning with acquisition tracking and pointing at accelerating rockets at range, then run through another series with an instrumented rocket with sensors to measure how well we are pointing our beacon illuminator laser and high-power laser," Rinn continues. "We'll do that [at] low and high power.

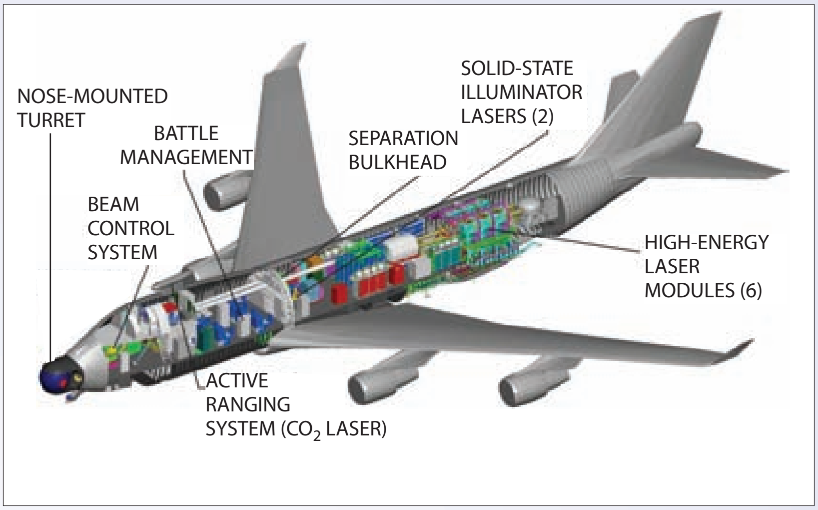
"Finally, we will fire high power against a foreign missile asset. The 2009 test is very important because, even though we have brought down the risk with all the different parts of the weapons system, there is nothing like flaming missile wreckage to show the world the system is viable and works."

Schedule and funding

Rinn believes ABL could be ready for combat application, using the test aircraft, as early as next year, much as the prototype J-STARS was deployed to the first gulf war. And while the primary stated mission is to shoot down enemy ballistic missiles in boost phase—that is, while they are still over their launch sites—he also says the technology could be applied elsewhere on the battlefield, further justifying the time and money invested in its development.

"Based on what I know of the system, I believe we will have some emergency deployment capability if the nation or our allies require it shortly after shootdown, in 2010. There are some limitations, clearly, such as logistics streams, and there is definitely more work to be done. But you would have a single ABL with some strong possibilities, similar to J-STARS during Desert Storm," he says. "In demonstrating the capability of this system, both for boost phase and potentially alternative missions—SAMs, cruise missiles, air-to-air missiles—there will be a tremendous potential.

"We're working with our customer to lay out the postmissile shootdown period, which will be driven by funding. The plan is to fly the first tail through a series of envelope expansions and potentially, if we can, work in some multimission stuff. But predominantly we will work with boosting missiles, engaging other targets at different ranges, different scenarios. It is imperative to keep the momentum going and move into deployment as soon as we can; there is some congressional language about affordability and military suitability that needs to be answered to allow us to go into a second aircraft."



Team ABL members are responsible for various elements of the system: Boeing is responsible for supplying the 747-400 Freighter, developing crew safety and the Battle Management system. Lockheed Martin is responsible for the nose-mounted turret, illuminator lasers, and beam-control system. Northrop Grumman is responsible for the system's COIL.

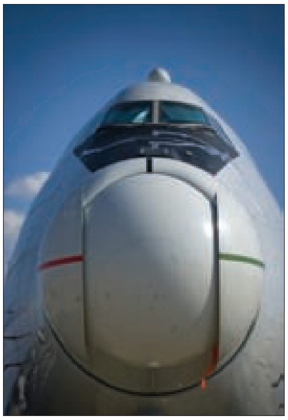
The next decision

McMurry expects a decision on a second aircraft in 2011-2012 and initial operational capability around 2018-2019. He says the go-ahead for a second aircraft, almost certainly another modified 747, would be based less on effectiveness and more on manufacturing and production qualities, with some marginal improvement in basic design characteristics, effectiveness, and performance. But the majority effort would be focused on getting a good production approach.

If a second aircraft is authorized, he adds, "the natural follow-on would be to ramp up to a full production fleet—currently envisioned as seven aircraft by Air Combat Command—along with a reasonable amount of training and sparing to maintain operational presence where needed.

"It is not entirely clear at this point whether the second aircraft would be an independent prototype or sort of an early production item. We're looking at whether it becomes the first of the fleet, which is my expectation, rather than building a second prototype, so we could move toward a fleet as soon as possible. The production timeline is similar to a satellite—about seven years, driven right now by the time to manufacture some of the larger optics, although there are other fairly long-lead elements in there as well," notes McMurry.

"We would be looking at a mid-2020s operational capability, with one new aircraft added each year, beginning with that second. You might go faster with a larger investment, but the expectation at this point is on a one-year center. We're not wed to the 747, but it does have to be a pretty large platform, and a great deal of learning has been done by the in-



A Lockheed Martin Space Systems engineer in the company's Sunnyvale, Calif., facility inspects the turret ball conformal window on the flight turret assembly for the ABL. The window is the exit for the high-energy laser and exit and return window for the beacon illuminator and tracker illuminator lasers.

dustry team on this aircraft. The big issue is, you need a large platform because of the last optic in the train, which is 1.7 m. That's a big lens, and the physics of the laser propagation are driven by the size of the last optic. So you need a large platform to have a large optic to have long-distance propagation of the beam."

Operationally, an ABL mission will resemble that of an AWACS or J-STARS, in terms of being escorted by fighter jets. In that respect, officials say they still need to determine exactly how the ABL will interact with combat aircraft, both enemy and friendly.

It has taken ABL a long time to reach the shootdown phase from its inception 13 years earlier, including a substantial restructuring of the schedule in 2005, some four years after it originally was expected to hit a missile in flight. As a result, the program's fight for funding and continuation has often equaled, if not exceeded, the technological challenges.

"There are critics saying we spent $5 billion to develop this technology, but if you look at ABL and other technologies, even some not so transformational, those numbers are well within the envelope of what these kinds of systems cost to develop and to get into the production phase," Rinn says. "There is still a lot of work to be done to drive the costs down, which I think already is happening," he says, noting the team has "shown how to set up a cost-effective production line.

"Also, there is a huge advantage this particular boost-phase weapon system brings to ballistic missile defense. Having the ability to thin the raid in a real ballistic missile warfare scenario, with a platform that can go anywhere in the world very quickly and stay on station for long periods, then use a speed-of-light weapon to destroy a missile in boost phase, is a very powerful asset. I think that's one reason we are still alive today, along with showing the technology really does work."

The challenges

The most serious problems ABL has encountered in recent years have involved optical coatings, some mechanical components, and some electronic and sensor issues, all of which Rinn says are fairly common in any major laser program.

"You can't just flip a switch and have somebody deliver a new part the next day. But [for] the worst issues I've seen, we were able to find work-arounds in days, weeks or, in worst cases, months, where we worked that fix in parallel with the rest of the program and then came back," Rinn points out. "I wouldn't say any of our problems have been unique, which is a testament to some of our design work and system integration trades. ABL began as a COTS rapid acquisition, something on which you inevitably get 'bit,' but the technology has matured.

"The thing about ABL and directed energy in general is there have been a lot of promises for years, while the technology was still maturing; but today the vast majority have matured, and we have demonstrated rapid firing and atmospheric ranges and have gotten through some problems considered nearly impossible in past years. Transformational technologies, such as computer chips, typically develop over a period of years or decades. Today, after a number of decades of laser technology efforts, we are at the beginning of these high-power and performance-level capabilities."

Even so, Rinn acknowledges concern about the possibility of new budget cuts, especially with a new administration taking over in Washington. But he believes ABL is now in a position to prove itself and what it will bring to warfighters and commanders—the ability to kill missiles at the speed of light.

"A system like this takes vision and a national will, and we are seeing a lot of support. Although the program has been around a number of years, with the recent breakthroughs, it is important to keep going," he says. "When decision-makers look at the system as a whole for boost phase and other missions, I think they'll see the added value there." [When Secretary of Defense Robert Gates released the Pentagon's budget propsal in April, ABL had moved to an experiment program and the number of aircraft was reduced to one. At this writing, the final outcome is undecided.]

Both he and McMurry also are concerned about the impact of any future delays on the industrial base supporting ABL technology.

"There are real issues, because there is a limited demand for these high-power optics; lower power tactical optics probably can feed off the telecom industry, but there are very limited vendors in optical coatings, adaptive optics (deformable and steering members), even some of the fluid mechanical components unique to a chemical laser," Rinn warns.

"So it is imperative that we fund ourselves enough to do this and spend money on a second airplane and not have a long gap before we start that. We need to get going on it right after shootdown. If we want to lead the world in directed energy technology, as we now do, we need to move on."