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MISSILE DEFENSE

Knowledge-Based Process Would Benefit Airborne Laser Decision-Making

Statement of Robert E. Levin, Director, Acquisition and Sourcing Management

Mr. Chairman and Members of the Subcommittee:

Thank you for inviting me. I am pleased to be here today to discuss the Missile Defense Agency's strategy for acquiring ballistic missile defense systems. Pursuant to your request, Mr. Chairman, we issued a report on July 12, 2002, that examined whether the Missile Defense Agency's new strategy for developing the Airborne Laser includes practices that are characteristic of successful developmental programs.[1] Our observations today will reflect the knowledge that we gained from that work.

If the Department of Defense is successful in its efforts to develop and field the Airborne Laser, it could be an important system because it would give the United States some capability to destroy enemy missiles over the enemy's own territory. Enemy states that could launch ballistic missiles with chemical or biological warheads toward the United States, its deployed troops, or allies could be deterred from doing so if that enemy knew that the chemical and biological agents might fall back to earth over its own territory.

When the Air Force launched the Airborne Laser program in 1996, it estimated that developing the system would cost $2.5 billion and that it would be fielded by 2006. However, by August 2001, the Air Force determined that maturing the technologies and developing the system would cost $3.7 billion, or about 50 percent more, and the system would not be fielded until 2010, 4 years later than originally planned. Against this backdrop of cost increases and schedule delays, the Department of Defense, in October 2001, transferred responsibility for the Airborne Laser from the Air Force to the Ballistic Missile Defense Organization, now known as the Missile Defense Agency.

Because of your interest in the agency's recently expanded responsibility and authority for acquiring a capability to protect against enemy ballistic missiles, you requested that today we

- describe the Secretary of Defense's specific direction to the agency;
- explain the agency's requirements-setting process and plans for testing;
- provide details on the agency's investment decision-making process;

[1] U.S. General Accounting Office, *Missile Defense: Knowledge-Based Decision Making Needed To Reduce Risks in Developing Airborne Laser*, GAO-02-631 (Washington, D.C.: July 12, 2002)..

- explain how the maturity of technology critical to the system's design will be measured;
- comment on the role of the Director, Operational Test and Evaluation; and
- remark on changes in the agency's test plans since Antiballistic Missile Treaty restrictions are no longer in place.

To address our objectives, we reviewed documents and held discussions with officials at the Boeing Company, Seattle, Washington; Lockheed Martin, Sunnyvale, California; TRW, Los Angeles, California; Airborne Laser Program Office, Kirtland Air Force Base, New Mexico; Missile Defense Agency, Arlington, Virginia; and the Office of the Director, Operational Test and Evaluation, Arlington, Virginia. We conducted our review from August 2001 through July 2002 in accordance with generally accepted government auditing standards.

In summary Mr. Chairman, we found the following:

- In January 2002, the Secretary of Defense directed the Missile Defense Agency to quickly develop a ballistic missile defense system that included various elements, such as the Airborne Laser. These elements are to work together to defend the United States, its deployed troops, allies, and friends by engaging enemy ballistic missiles at various points during their flight. The Secretary also directed the agency to cancel existing requirements documents and, instead, develop elements with currently available technology that would be capable of defeating some, if not all, of the threat. This capability could then be improved over time.

- In response to this direction, the agency adopted changes that are characteristic of successful development programs. First, the agency adopted a flexible requirements-setting process that allows it to refine system requirements based on the results of system engineering. This process can result in less risk of cost and schedule growth because it does not establish requirements until systems engineering shows what is achievable. However, the agency must set the Airborne Laser's requirements when it determines that it has a match between the technology, money, and time needed to design and demonstrate an operational system so that the agency can use those requirements to measure the progress being made during product development. The agency is also implementing other changes to improve Airborne Laser's development. For example, the agency is allowing more time to mature and test technologies critical to the system's design, and it is improving

ground test facilities so that in the future improved components can be tested on the ground before being installed in an aircraft.

- The agency has not yet implemented another practice that has proven beneficial in successful development programs and that we recommended to the agency in our July 12 report. Successful developers make decisions on whether to proceed with a program when the focus and cost of their activities are about to change. The criteria for beginning new activities is a determination by the developer that the program has the knowledge to begin the activities and that investing in them is the best use of the developer's resources. Our work over the years has found that the focus and cost of activities will change when the program is ready to move from technology development to system integration, then again into system demonstration, and finally on into production. Although, the Missile Defense Agency does not currently make decisions at each of these points or use the same criteria proven by successful developers, the agency is considering how to implement such a process.

- The Airborne Laser Program Office used technology readiness levels to assess the maturity of the technology critical to the design of the Airborne Laser. Our work shows that developers greatly enhanced their likelihood of success by beginning development only when they had demonstrated a system prototype in an operational environment. The program office's assessment showed that some Airborne Laser technology is almost to this point, but technology such as the mirrors and windows that focus and control the laser beam and allow it to pass safely through the aircraft (collectively referred to as optics) require additional engineering work before reaching this stage of maturity. Except for its evaluation of the laser, we agreed with the program office's technology assessment. We believe further testing is needed to demonstrate the maturity of the laser technology because the program has only tested a one-module laser (rather than the six-module laser planned for the first Airborne Laser configuration) in a controlled laboratory environment using surrogate components.

- By law, the Director of Operational Test and Evaluation (OT&E) is responsible for operational rather than developmental testing. However, OT&E officials said that being involved in developmental tests provides them insight and understanding to prepare for live-fire testing and later operational testing and evaluation. The officials told us that they have primarily been working on issues related to future live-fire lethality tests of the Airborne Laser, but they expect their

involvement in Airborne Laser's developmental tests will increase when system-level flight tests begin. The OT&E Director has not been given authority to approve Airborne Laser's developmental test and evaluation master plan, but OT&E officials have been asked to assist agency officials in preparing the plan and will provide comments before the plan is finalized.

- The Airborne Laser Program Office said that the United States' withdrawal from the Antiballistic Missile Treaty has not changed its plan to initially test the first Airborne Laser configuration against a short-range ballistic missile. However, the agency is considering future tests with longer-range missile targets. Such tests, which would have been restricted by the treaty, could occur in fiscal year 2005 or 2006.

Defense Secretary Directs New Approach for Acquiring and Deploying Missile Defenses

In 2001, the Department of Defense conducted missile defense reviews to determine how to best fulfill the nation's need to defend against enemy ballistic missile attacks. As a result of these studies, the Secretary of Defense in January 2002 directed that the Ballistic Missile Defense Organization be elevated to the status of an agency and renamed as the Missile Defense Agency. The Secretary's key priorities were to field quickly an integrated missile defense system that could defend the United States, deployed forces, allies, and friends by engaging enemy ballistic missiles at various points during their flight. Another of the Secretary's priorities was to provide an early capability by using test assets or prototypes in the event of an emergency. To enable the agency to achieve his priorities, the Secretary directed the agency to abandon its traditional requirements-setting process that required a military service to establish technical requirements when a weapon system acquisition program was launched and adopt a more flexible, capability-based process that would allow the agency to use available technology to develop a weapon system that could engage some, if not all, of the current threat. This "base-line" capability would then be improved over time. The Airborne Laser system was one of many systems affected by these changes.

Agency Adopts New Requirements-Setting Process and Other Practices

In response to the Secretary's direction, the Missile Defense Agency adopted a new Airborne Laser development strategy that incorporates some of the practices characteristic of successful programs. These practices include a more flexible requirements-setting process, allowing more time to mature and test the Airborne Laser's critical technologies, and improving test facilities.

Our work shows that the flexible requirements-setting process can result in less risk of cost and schedule growth because requirements are not set until systems engineering shows what is achievable. However, the agency must set the Airborne Laser's requirements once it determines that it has a match between the technology, money, and time needed to design and demonstrate an operational system so that the agency can use those requirements to measure the progress being made during product development.

The Department of Defense ordinarily faces significant hurdles in matching requirements to available resources (time, technology, and money). The fundamental problem is two-fold. First, under the Department's traditional process, requirements must be set before a program can be approved and a program must be approved before the product developer conducts systems engineering. Second, the competition for funding encourages requirements that will make the desired weapon system stand out from others. Consequently, many of the Department's product development programs include unrealistic requirements set by the user before the product developer has conducted the system engineering necessary to identify the time, technology, and money necessary to develop a product capable of meeting requirements.

The agency is also adopting other practices that are likely to improve Airborne Laser's development. These practices include allowing more time for testing and developing facilities to mature and test critical technologies. The agency is initially developing and testing a six-module laser system to demonstrate technologies critical to the Airborne Laser's design. When the Air Force was responsible for the Airborne Laser program, it planned to complete system-level flight tests of the six-module Airborne Laser system in the last quarter of fiscal year 2003, but the agency has delayed completion of the test to the first quarter of fiscal year 2005. This delay allows additional time to learn from and correct problems discovered during the tests. In addition, the agency plans to increase the Airborne Laser's ground-testing capability by awarding a contract in 2003 for what they are calling an "iron bird," which is essentially an aircraft hull with laser equipment installed. The "iron bird" is expected to allow testing of a fully integrated Airborne Laser system on the ground so that technologies for future configurations can be evaluated before being installed in an aircraft.

Allowing more time for testing is important because testing informs the requirements process. Because testing allows developers to gauge the progress being made in translating an idea into a weapon system, it

enables the developer to make a more informed decision as to whether a technology is ready to be incorporated into a system's design. With this knowledge, the developer can determine whether the technology is so important to the system's design that additional time and money should be spent to mature the technology or whether the system's initial performance requirements should be reduced.

The "iron bird" is expected to reduce the cost of testing technologies planned for future Airborne Laser configurations. With it, the agency can mature new component-level technologies to higher levels in the less expensive ground-testing environment before installing them on an aircraft.

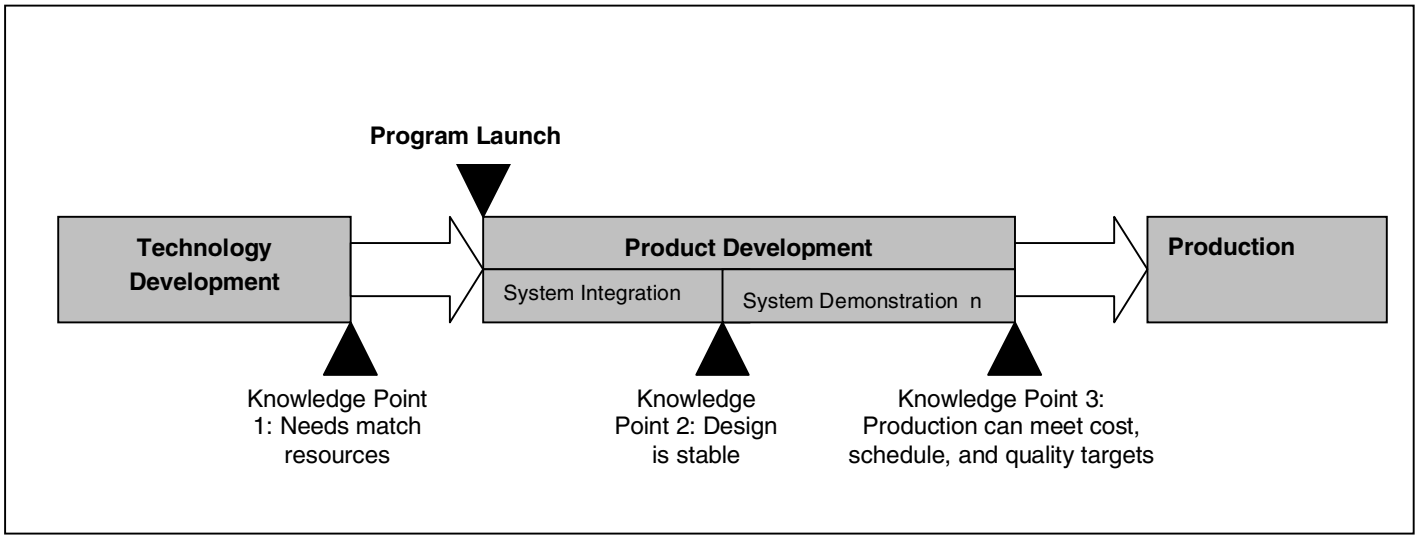
Changes in Agency's Decision-Making Process Are Needed

We reported in July 2002, that the Missile Defense Agency's new Airborne Laser acquisition strategy does not include decision points with appropriate knowledge-based criteria for moving the Airborne Laser program forward. However, the agency is now considering how it can implement such a process.

In successful developments, developers make decisions when the focus and cost of program activities is about to change. At these points, the developers decide whether they have the knowledge to begin new activities and whether investing further time and money in their product is the best use of their resources. The first decision point occurs when the focus of the developer's activities change from technology development to system integration. This point is reached when the developer has incorporated technology into subcomponents with the form, fit, and function needed in an operational system and the developer is ready to design a system that integrates those subcomponents. The criterion for deciding to move the program forward is having the knowledge to match requirements and available resources (time, technology, and funds). The second decision point occurs between system integration and system demonstration when the developer has successfully integrated subsystems and components into a design that not only meets the customer's performance requirements but also has optimized the design for reproducibility, maintainability, and reliability. A developer moves the program forward at this point only if the design is stable, which is generally considered to be the point at which about 90 percent of the design's engineering drawings have been released. The third decision point separates system demonstration from production. The decision to invest in production is based on having the knowledge to determine that the product performs as required during testing and that the manufacturing

processes will produce a product within cost, schedule, and quality targets.

Figure 2: The Knowledge-Based Process



Decisions are made at these points not only because the focus of activities is changing, but also because the cost of the activities are increasing. Our work shows that product development is typically much more costly than technology development. This is because during technology development, small teams of technologists work to perfect the application of scientific knowledge to a practical problem. As product development begins, developers begin to make larger investments in human capital, bringing on a large engineering force to design and manufacture the product. In addition, product development requires significant investments in facilities and materials. These investments increase continuously as the product approaches the point of manufacture.

The Airborne Laser acquisition process has three phases separated by two decision points. The phases are development, transition, and procurement. The development phase includes all developmental activities and system level demonstrations of military utility. Transition includes preparation of the operational requirements document by the appropriate armed service and operational testing; and production includes producing and fielding the weapon system. The first decision point occurs between development and transition. A decision will be made to begin the transition phase if the

agency determines that it has the technology in-hand to produce a system that merits fielding. At the end of the transition phase, the Airborne Laser would enter the formal Department of Defense acquisition process at Milestone C—the point at which the Department decides whether a system should begin low-rate initial production.

The Missile Defense Agency's current decision-making process puts at risk the agency's ability to develop a useful military capability on time and within budget. This is because the agency's process does not include an established set of decision points with appropriate knowledge-based criteria for deciding whether to invest in system integration and, subsequently, system demonstration and production. For example, the agency does not separate technology development from system integration with a decision point or use the knowledge the program has attained to determine if the technology can be incorporated into a mature system design within available time and funding constraints. Agency officials are considering how to fit such decision points into Airborne Laser's acquisition process, as well as the acquisition process of other elements.

Technology Readiness Levels Are Used to Measure Technology Maturity

In 2002, the Airborne Laser Program Office assessed the maturity of technologies critical to the development of the Airborne Laser system. To make this assessment, the program office used a tool known as technology readiness levels that was developed by the National Aeronautical and Space Administration. A comparison of a 1999 assessment and the 2002 assessment shows that the Airborne Laser program has made progress in maturing critical technologies, but much remains to be done.

In 1996, the Air Force launched the Airborne Laser program to develop a defensive system that could destroy enemy missiles from a distance of several hundred kilometers. Engineers concluded that if they were to meet this requirement, the system would need a fourteen-module oxygen iodine laser. They also determined that the system would need a beam control/fire control assembly that could (1) safely move the laser beam through the aircraft, (2) shape the beam so that it would not be scattered or weakened by the atmosphere, and (3) hold the beam on target despite the movement of the aircraft. In addition, engineers determined that the system would need a battle management and control system capable of planning and executing an engagement. To determine if the technology was "in hand" to meet this requirement, the Air Force planned to build a

six-module Airborne Laser configuration and test it against a short-range ballistic missile. Under the Missile Defense Agency's new development strategy, this six-module configuration is now known as Block 2004.[2]

Officials began their 2002 assessment by determining the technologies critical to designing Block 2004 and future configurations. These technologies are: (1) devices that stabilize the laser system aboard the aircraft so that the beam can be maintained firmly on the target; (2) optics—mirrors and windows—that focus and control the laser beam and allow it to pass safely through the aircraft; (3) optical coatings that enhance the optics' ability to pass laser energy through the system and to reflect the laser energy; (4) hardware that works in tandem with computer software to actively track the target missile; (5) devices that measure atmospheric turbulence and compensate for it so that it does not scatter or weaken the laser beam; and (6) safety systems that automatically shut down the high energy laser in the event of an emergency. At our request, the Airborne Laser Program Office also assessed the maturity of the oxygen iodine laser.

The program office assessed the optics and stabilizing devices at technology readiness level four, the optical coatings at level five, and the safety systems, atmospheric compensation, and target tracking devices at level six. At level four, scientists have shown that a technology is technically feasible, but have not shown whether the technology will have the form, fit, or function required in the operational system. When a technology progresses to level five, the technology being tested is incorporated into hardware whose form and fit are coming closer to that needed for an operational component and that hardware is integrated with reasonably realistic supporting elements so that the technology can be tested in a simulated environment. Finally, at technology readiness level six, integrated testing of a prototype system has occurred in a relevant environment. Our prior work has shown that demonstrating a technology readiness level of seven, that is, demonstrating that components can work together as a system in a realistic setting, prior to establishing cost and schedule estimates and beginning system integration, is an important determinant of program success.

[2] This configuration is known as Block 2004 because it is to be completed in December 2004.

We disagreed with the agency's assessment in only one instance—the assessment of the maturity of the system's laser component. The agency assessed the maturity of the oxygen iodine laser at a readiness level of six while we consider it to be at a level four. The tests of a one-module laser that the program office relied upon to prove the maturity of the laser were conducted in a controlled laboratory environment with surrogate components. In our opinion, the program office will demonstrate the laser technology in a relative environment (technology readiness level six) when the six-module system is integrated and successfully tested at full power within the high fidelity laboratory environment of the Airborne Laser Systems Integration Laboratory, currently under construction at Edwards Air Force Base, California.

Operational Test Community Expects to be Involved in Developmental and Operational Testing

By law, the Director of the Office of Operational Test and Evaluation (OT&E) is the principal advisor to the Secretary of Defense and the Under Secretary of Defense for Acquisition, Technology, and Logistics on operational test and evaluation of Department of Defense weapon systems and is also responsible for monitoring and reviewing live fire testing activities.[3] The Director may not be assigned any responsibility for developmental test and evaluation, other than to provide advice to officials responsible for such testing. However, OT&E officials said that being involved in developmental tests aids them in preparing for live fire testing and later operational testing and evaluation, for which they are responsible.

The officials told us that they have primarily been working on issues related to future live-fire lethality tests of the Airborne Laser, but they expect their involvement in Airborne Laser's developmental tests will increase when system-level flight tests begin. This expectation is based on the agency's request that the OT&E officials work with Missile Defense Agency officials to construct developmental test and evaluation master plans for the integrated missile defense system and each element. Although OT&E has not been given authority to approve the Airborne Laser's developmental test and evaluation master plan, OT&E officials said that they will assist in preparing the plan and will review and offer comments before it is finalized.

[3] 10 USC 139

In addition to participating in the creation of the developmental test and evaluation master plans, the Director, OT&E, will participate in approving each element's operational test plan and will evaluate their operational tests. Further, under the agency's new strategy, OT&E officials are members of the Missile Defense Support Group and its working group. These groups are expected to provide insight and advice to the Missile Defense Agency Director and to the Senior Executive Council that is responsible for all major missile defense decisions. The agency has also assured the operational test community that it will be included in all meetings and reviews regarding testing so that test officials can annually review and report on the adequacy and sufficiency of the Missile Defense Agency's testing program.

Targets in Future Tests Could Change

Airborne Laser program officials told us that the Airborne Laser was originally planned as defense against short-range ballistic missiles. However, with the United States withdrawal from the Antiballistic Missile Treaty, the Missile Defense Agency is considering tests against longer-range missiles. While such a change would not affect the program office's plan to test the Airborne Laser against a short-range missile in December 2004, tests conducted in fiscal year 2005 or 2006 could include targets representative of longer-range missiles. The Antiballistic Missile Treaty would have restricted tests that include longer-range missiles as Airborne Laser targets.

Conclusion

In an effort to field a missile defense capability quickly, the Department of Defense has directed the Missile Defense Agency to adopt a new acquisition strategy. Some of the practices that we observed are being implemented in the Airborne Laser program are practices that have been proven in successful development programs. For example, similar to successful developers, the agency has deferred the establishment of the Airborne Laser's requirements until the knowledge is available to set realistic requirements. Successful developers also improve their product incrementally, just as the agency plans to improve the Airborne Laser through a series of upgrades. However, the agency has the opportunity to make its acquisition process more knowledge-based. By establishing knowledge-based decision points at key junctures, the agency would be in a better position to decide whether to invest in the next phase of the Airborne Laser's development. Also, the agency would be better able to hold the Airborne Laser Program Office accountable for planning all of the activities required to develop a quality product, approaching those activities in a systematic manner so that no important steps are skipped

and problems are resolved sooner rather than later, and making cost and schedule projections when they have the knowledge to make realistic estimates. With this disciplined process in place, the agency will be much better positioned to decide whether to invest further in the Airborne Laser or use available time and funds for some other element of the missile defense system.

Our July 12 report recommended that the Director of the Missile Defense Agency not only establish decision points to separate technology development from system integration; system integration from system demonstration; and system demonstration from production, but also establish knowledge-based criteria that would be used to determine whether additional investments should be made in the Airborne Laser program. We are encouraged that the agency is now considering actions that could prove to be significant steps toward implementing these recommendations.

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Mr. Chairman, this concludes my statement. I would be pleased to respond to any questions you or members of the committee may have.