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Report to Congressional Requesters

March 1999

DEFENSE ACQUISITIONS

DOD Efforts to Develop Laser Weapons for Theater Defense

GAO/NSIAD-99-50

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National Security and
International Affairs Division

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March 31, 1999

The Honorable Owen B. Pickett
Ranking Minority Member
Subcommittee on Military Research and Development
Committee on Armed Services
House of Representatives

The Honorable John M. Spratt, Jr.
Ranking Minority Member
Committee on the Budget
House of Representatives

This report responds to your request that we conduct a review of Department of Defense (DOD) programs to develop laser weapons for missile defense. Specifically, you asked us to (1) identify what laser weapons are being considered for missile defense and the coordination among the program offices developing the systems, (2) determine the current status and cost of each system, and (3) identify the technical challenges each system faces as determined by DOD program managers and analysts and other laser system experts. The report recommends that the Secretary of Defense direct the Secretary of the Air Force to reconsider plans to exercise the option for the second ABL aircraft for the engineering and manufacturing development phase of the Airborne Laser program before flight testing of the Airborne Laser system developed during the program definition and risk reduction phase has demonstrated that the Airborne Laser concept is an achievable, effective combat system.

We are sending copies of this report to Senator Pete V. Domenici, Senator Daniel K. Inouye, Senator Carl Levin, "Senator Frank R. Lautenberg, Senator Joseph I. Lieberman, Senator Rick Santorum, Senator Ted Stevens, Senator John W. Warner, Representative Duncan L. Hunter, Representative John R. Kasich, Representative Jerry Lewis, Representative John P. Murtha, Representative David R. Obey, Representative Norman Sisisky, Representative Ike Skelton, Representative Floyd D. Spence, Representative Curt Weldon, and Representative C.W. Bill Young in their capacities as Chair or Ranking Minority Member of Senate and House Committees and Subcommittees. We are also sending copies of this report to the Honorable William Cohen, Secretary of Defense; the Honorable F. Whitten Peters, Acting Secretary of the Air Force; the Honorable Louis Caldera, Secretary of the Army; the Honorable Jacob Lew, Director, Office of Management and Budget; and Lieutenant General Lester L. Lyles, Director, Ballistic Missile Defense Organization. Copies will also be made available to others on request.

Please contact me at (202) 512-4841 if you or your staff have any questions concerning this report. Major contributors to this report are listed in appendix II.

Louis J. Rodrigues
Director, Defense Acquisitions Issues

Executive Summary

Purpose

The Ranking Minority Member, House Committee on the Budget, and the Ranking Minority Member, Subcommittee on Military Research and Development, House Committee on Armed Services, asked GAO to review the Department of Defense's (DOD) programs to develop laser weapons for missile defense to (1) identify the laser weapons being considered for missile defense and the coordination among the program offices developing the systems, (2) determine the current status and cost of each system, and (3) identify the technical challenges each system faces as determined by DOD program managers and analysts and other laser system experts.

Background

DOD is developing a variety of weapon systems as part of its Theater Missile Defense program. The first generation of these weapons uses interceptor missiles to intercept and destroy enemy missiles in the latter stages of their flight. Included among these systems are the Patriot Advanced Capability-3, an improved version of the Patriot system that was used during the Gulf War; Navy Area Defense; Medium Extended Air Defense System; Theater High Altitude Air Defense; and Navy Theater Wide system.

In addition, DOD is developing ballistic missile defense systems that will use laser beams to destroy enemy missiles. These systems, as well as a system that is to be used to destroy short-range artillery rockets, are the focus of this report.

Results in Brief

DOD is developing two laser weapons–the Airborne Laser (ABL) and the Space-Based Laser (SBL)–which U.S. forces intend to use to destroy enemy ballistic missiles. Additionally, in a joint effort with Israel, DOD is developing a ground-based laser weapon, the Tactical High Energy Laser (THEL), which Israel will use to defend its northern cities against short-range rockets. ABL is funded and managed by the Air Force, SBL is jointly funded by the Ballistic Missile Defense Organization and the Air Force and managed by the Air Force, and THEL is funded jointly with Israel and managed by the Army. The respective program offices are coordinating the development of these programs through various means of information sharing.

ABL, SBL, and THEL are in varying stages of development ranging from conceptual design studies to integration and testing of system components.

- The ABL program is in the program definition and risk reduction (PDRR) acquisition phase[1] and is scheduled for full operational capability in 2009, with a total of seven ABLs. This schedule reflects a 1-year delay from the original schedule. The Air Force attributes this slippage to a congressional funding cut and to an expanded test program. The Air Force estimates the life-cycle cost of the ABL to be about $11 billion.
- The SBL program is about a year into a $30-million study phase to define concepts for the design, development, and deployment of a proof of concept demonstrator. DOD estimates that it will cost about $3 billion to develop and deploy the demonstrator. The future of the SBL program is unknown at this time, pending the outcome of a DOD assessment of the program.
- The $131.5-million THEL Advanced Concept Technology Demonstration program is about 34 months into a 38-month program. System components have been built, but system testing has been delayed from December 1998 to July 1999 due to administrative and technical problems. The United States is contributing $106.8 million toward the program cost and Israel is contributing $24.7 million.

Laser experts agree that the ABL, SBL, and THEL face significant technical challenges. The ABL program has made progress in addressing some technical challenges, such as completing the collection of non-optical atmospheric turbulence data from the Korean and Middle East theaters. However, in commenting on a draft of this report, DOD officials stated that while the Air Force's analyses of these data argue that the design specification established for atmospheric turbulence is generally accurate, DOD has yet to reach a final position on this issue. The technical complexity of the ABL program has caused some laser experts to conclude that the ABL planned flight test schedule is compressed and too dependent on the assumption that tests will be successful and therefore does not allow enough time and resources to deal with potential test failures and to prove the ABL concept. GAO believes that the Air Force should reconsider its plan to order a second ABL aircraft before flight tests demonstrate that the ABL system can shoot down enemy ballistic missiles.

[1]This phase consists of steps necessary to verify preliminary design and engineering, build prototypes, accomplish necessary planning, and fully analyze trade-off proposals. The objective is to validate the choice of alternatives and to provide the basis for determining whether to proceed into the next phase (engineering and manufacturing development) of the acquisition process.

SBL program management has characterized the SBL demonstrator as the most complex spacecraft the United States has ever attempted to build. If DOD ultimately decides to continue the program, the size and weight limitations dictated by current and future launch capabilities will force the program to push the state of the art in areas such as laser efficiency, laser power, and deployable optics.

THEL's components have been produced. However, initial testing of the laser has identified problems with the operation of the chemical flow control valves and with the low-power laser that is to be used in tracking short-range rockets the system is being designed to defeat.

Principal Findings

DOD Developing Three Defensive Laser Weapons

The ABL is expected to be DOD's first system to intercept and destroy enemy missiles in their boost phase several hundred kilometers away. The program involves placing multimegawatt lasers, beam control systems, and related equipment, in a fleet of seven Boeing 747-400 freighter aircraft.

The SBL is to be DOD's first space-based laser weapon and is designed to provide a continuous global boost phase intercept capability for both theater and national missile defense. Proposed concepts call for placing multimegawatt chemical lasers, beam control systems, and related components on a constellation of 20 to 35 satellites. Each SBL is to be capable of destroying about 100 missiles and is to have a range of about 4,300 kilometers.

The THEL is a ground-based weapon that is being designed to destroy Katyusha[2] and other short-range rockets. It is to detect an incoming rocket, track the rocket's path, and hold a concentrated laser beam on the rocket's warhead until the beam's heat causes the warhead to detonate, destroying the rocket. THEL is not designed to be powerful and mobile enough to meet U.S. needs.

[2]According to THEL program officials, the Katyusha rocket has a range of 8 to 24 kilometers, with a flight time of 20 to 80 seconds. Its boost phase is about 1.5 seconds.

Coordination Among the Programs

The directors for the three laser development programs are coordinating their efforts by meeting periodically to share information on technology and development issues. In addition, some of the same contractors and contractor personnel are involved in all three programs, thereby increasing program coordination. Further, all three programs have benefited from work performed by the Air Force Research Laboratory.

Status and Cost of the Laser Weapon Programs

The ABL program is currently in the PDRR acquisition phase. In November 1996, the Air Force awarded the PDRR contract to the team of Boeing, TRW, and Lockheed Martin. Under this contract, Boeing is to produce and modify a 747-400 freighter aircraft and integrate the laser and beam control system with the aircraft; TRW is to develop the chemical oxygen iodine laser and ground support systems; and Lockheed Martin is to develop the beam control system. One prototype ABL is to be produced and used in 2003 in attempts to shoot down missiles in their boost phase. This schedule reflects a 1-year slip in the original PDRR schedule. According to the program office, this slip is due to a $25-million reduction made by Congress in the fiscal year 1999 appropriation for the ABL and to an expanded test program. If the 2003 demonstration is successful, the program is to move into the engineering and manufacturing development phase. The Air Force estimates the life-cycle cost of the ABL to be about $11 billion, including $1.6 billion for the PDRR phase, $1.1 billion for the engineering and manufacturing development (EMD) phase, $3.6 billion for the production phase, and $4.6 billion for 20 years of operations and support.

The SBL program office awarded two 6-month, $10 million contracts in February 1998 to Lockheed Martin and TRW to obtain information needed to develop an acquisition plan. It planned to award another contract in August 1998 for the design, development, and deployment of the demonstrator. However, that contract was not awarded because, in August 1998, the Under Secretary of Defense for Acquisition and Technology directed the Air Force to restructure the SBL strategy, including considering other alternatives to the SBL. The Air Force's restructured strategy shows that a demonstrator would not be launched until the 2010 to 2012 time frame, due to the immaturity of the required technology and the projected program funding. The restructured strategy has not received final approval and is not consistent with Congress' desire to launch the SBL readiness demonstrator in the 2006 to 2008 time frame. At the time of GAO's review, Ballistic Missile Defense Organization (BMDO) officials did not know when or if the proposed restructured acquisition strategy will be approved and ultimately submitted to Congress. If the SBL is ultimately selected to proceed, DOD estimates that a fully operational system would not be deployed until after 2020.

The $131.5 million THEL system, which is being developed by TRW and Israel, is scheduled to be the first of the three systems fielded, albeit not for U.S. use. The program is about 34 months into a 38-month program. The United States and Israel are contributing $106.8 million and $24.7 million toward the program cost, respectively. All system components have been built and are in varying stages of testing and integration. Testing at White Sands Missile Range against Katyusha rockets, originally scheduled for December 1998, is now scheduled for July 1999, due to administrative issues and technical problems with the laser and tracking system.

Technical Challenges Face Each System

While individual components of the proposed systems have been tested under laboratory conditions and the program offices have conducted modeling and computer simulations, none of the systems has been fully integrated and tested as a complete weapon system. Until this is accomplished, it is not possible to predict with any degree of certainty the probability that these laser programs will evolve into viable defense systems.

The ABL program has made progress in addressing some technical challenges. However, other challenges remain as do concerns about some Air Force statements of program successes. Specifically, Air Force statements that the flight-weighted laser module[3] exceeded power output requirements are questionable because a major component of the module did not meet ABL design specifications. Further, the Air Force states that it met the beam quality requirement for the laser module; however, it has not yet measured the quality of an actual laser beam generated by the module. Instead, during the initial tests, beam quality was estimated using computer models and measurements of the chemical flows within the laser. The complexity of the ABL system indicates that initiating the hot fire flight testing only 4 months prior to the 2003 theater ballistic missile shoot down tests is not adequate. In that regard, the Air Force Scientific Advisory Board stated that, "past experience with high power laser systems and large beam directors suggests that new and difficult problems will surface in that [flight test] phase, and many flights and targets will be needed to

[3]A laser module that is of the size and weight that can be carried by the ABL aircraft.

sort them out." Given these complexities, the Air Force's plan to order a second ABL aircraft, about 1 year before the weapon system developed during the PDRR phase, attempts to demonstrate that the proposed ABL system can shoot down an enemy theater ballistic missile, should be reconsidered.

The high level of technical challenges facing the SBL program is exemplified by a statement a senior SBL program official made to GAO that there was a 50-percent chance of being able to build and deploy the SBL concept demonstrator by 2008 (one of the then-current deployment goals). According to this official, the SBL demonstrator would be the most complex spacecraft the United States has ever built. The major reasons for this technical complexity are the weight and size constraints dictated by the limited payload capabilities of current and future launch vehicles. These constraints will force the program to push the state of the art in areas such as laser efficiency, laser power, and deployable optics.

A 7-month schedule delay in the THEL program illustrates the technical challenges the program must overcome. Testing against Katyusha rockets at White Sands Missile Range, New Mexico, was to occur in December 1998, but has now slipped until July 1999 due to administrative issues associated with contract initiation and technical problems with the laser and tracking system. The initial tests of the laser revealed leaks in the specialized valves that control the flow of chemicals through the laser. These leaks must be corrected because they would detract from the performance of the laser. In addition, testing of the pointer tracker system disclosed a problem with the low-power laser that is to be used in tracking incoming short-range rockets.

Recommendation

Regarding the ABL program, GAO recommends that the Secretary of Defense direct the Secretary of the Air Force to reconsider exercising the option for the second ABL aircraft for the EMD phase of the program until flight testing of the ABL system developed during the PDRR phase has demonstrated that the ABL concept is an achievable, effective combat system.

Agency Comments and GAO's Evaluation

In a draft of this report, GAO recommended that the Secretary of Defense direct the Secretary of the Air Force to provide DOD an assessment of the need to expand the ABL flight test program. In commenting on that draft report, DOD partially concurred with GAO's recommendation and stated that its ongoing assessment of the ABL program by an Independent Assessment Team (IAT) would constitute an appropriate assessment of the flight test program.[4]

Subsequent to DOD's comments on GAO's draft report, DOD completed its assessment of the ABL program and reported the results to Congress in March 1999. In its report, DOD noted the IAT's agreement with Air Force plans to restructure the ABL program to expand testing and risk reduction activities before starting modifications to the PDRR aircraft (the first aircraft). DOD concurred with the IAT's recommendation for more testing of the PDRR aircraft before Milestone II, which governs entry into engineering and manufacturing development. DOD stated that it will review the Air Force's proposed restructured program and set a new Acquisition Program Baseline in the spring of 1999. During the restructuring and rebaselining effort, DOD stated that, among other things, it will revise the exit criteria for Milestone II to require more testing against threat-representative targets.

DOD stated that it expects that adding flight tests to the program before the start of EMD will increase near-term costs and might delay ABL's achievement of an initial operational capability. However, according to DOD, the added tests will ensure that the expenditures required for ABL's EMD phase are justified.

GAO agrees with DOD's assessment and future plans for the ABL program. Therefore, GAO deleted from its final report the recommendation for an assessment of the ABL flight test program.

Based on DOD's comments on GAO's draft report that DOD would not necessarily incur unnecessary costs by proceeding with the purchase of a second ABL aircraft, GAO revised its recommendation to reflect the need for DOD to reconsider its planned purchase in light of the IAT's findings and GAO's report.

GAO recognizes that delaying the procurement of the aircraft for the EMD portion of the program until after the ABL demonstrates it can shoot down target missiles might require a change in the scheduled initial operational

[4]This assessment was required by the Strom Thurmond National Defense Authorization Act for Fiscal Year 1999.

capability. However, such a slip would ensure that the procurement of the EMD aircraft would then be based on the additional knowledge gained in the shoot down demonstrations that the ABL design is feasible. GAO's approach is consistent with DOD's March 1999 report to Congress on the ABL program wherein it accepted a potential delay in the ABL's initial operational capability in favor of obtaining additional data through increased flight tests. GAO's approach is also appropriate in view of the discussion in DOD's March 1999 report on the impact of turbulence on the ABL design specification. DOD stated that optical turbulence in excess of the design specification along the slant path between the ABL and its target can reduce ABL's maximum lethal range and increase required dwell times, even at lesser ranges. It said that some analyses of atmospheric turbulence data collected in theaters of interest to date suggest that turbulence levels well above assumed ABL design levels might occur more often than expected at the time the design levels were set. According to DOD, there are currently no clear methods for predicting the actual turbulence level along a slant path to a particular threat location at a given point in time. Thus, according to DOD, beyond trial and error, it is not clear how a correct decision can be made on whether a particular target can be successfully engaged when launched near ABL's maximum lethal range. The Air Force is analyzing turbulence data and investigating tactical decision aids for the system to address this issue.

DOD's comments are reprinted in appendix I. DOD also provided separate technical comments that we have incorporated in this report where appropriate.

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Tables

Figures

Abbreviations

ABL	Airborne Laser
AFRL	Air Force Research Laboratory
ATP	Authority to Proceed
BMDO	Ballistic Missile Defense Organization
DOD	Department of Defense
EMD	engineering and manufacturing development
HELSTF	High-Energy Laser Systems Test Facility
PDRR	program definition and risk reduction
SBL	Space-Based Laser
SBLRD	Space-Based Laser Readiness Demonstrator
SMDC	Space and Missile Defense Command
THEL	Tactical High-Energy Laser

Chapter 1

Introduction

The Department of Defense (DOD) and Congress have become increasingly concerned that U.S. and allied troops abroad may be attacked by chemical, biological, or nuclear weapons delivered by ballistic missiles. Operation Desert Storm demonstrated that the U.S. military and other allied forces have limited capability against theater ballistic missiles. In fact, U.S. defensive capability is limited to weapons that defend against missiles nearing the end of their flight, such as the Patriot.[1] Consequently, developing weapon systems to defeat these threats is DOD's top priority in its overall ballistic missile defense program.

DOD has been working with laser technology for a long time. The following table shows some of the laser development efforts that DOD has undertaken. To date, none of these efforts has resulted in an operational laser weapon system.

Table 1.1: Examples of DOD Laser Development Efforts

Development effort	Purpose	Inception date
Tri-Service Laser Program	Develop carbon dioxide gas dynamic laser	1968
Navy-Advanced Research Projects Agency Chemical Laser Program	Develop high-energy chemical laser	1971
Airborne Laser Laboratory	Demonstrate the feasibility of using a high-energy laser in an airborne environment	1972
Mid-Infrared Advanced Chemical Laser	Develop and integrate a ground-based high-energy chemical laser with a beam control system	1977
Space-Based Laser Program	Develop space-based high-energy chemical laser weapon system	1977
Ground-Based Laser (free electron)	Develop high-energy free electron laser weapon system	1979
Ground-Based Laser (Excimer)	Develop high-energy excimer laser weapon system	1979

[1]The Patriot system was initially deployed in 1985 as an anti-aircraft weapon and modified in the late 1980s to defend against ballistic missiles as well. It has a range of about 40 miles.

Currently, DOD is developing a variety of weapon systems as part of its Theater Missile Defense program to counter the potential threats posed by ballistic missiles. The first generation of these weapon systems uses interceptor missiles to intercept and destroy enemy missiles in the latter stages of the missiles' flight. Included among these systems are the Patriot Advanced Capability-3, an improved version of the Patriot system that was used during the Gulf War; Navy Area Defense; Medium Extended Air Defense System; Theater High Altitude Air Defense; and Navy Theater Wide.

In addition, DOD is developing ballistic missile defense systems that will use laser beams to destroy enemy missiles. DOD plans to spend billions of dollars to develop these laser weapons and place them in the air (Airborne Laser)[2] and in space (Space-Based Laser). In addition, DOD is developing a ground-based laser (Tactical High-Energy Laser) that is to be used to destroy short-range artillery rockets.

Congress has generally endorsed DOD's efforts to develop and produce these laser weapon systems. Its desire to have these systems developed, produced, and deployed as soon as possible was heightened by a July 1998 report by the Commission to Assess the Ballistic Missile Threat to the United States.[3] The Commission concluded, among other things, that concerted efforts by a number of overtly or potentially hostile nations to acquire ballistic missiles with biological or nuclear warheads pose a growing threat to the United States, its deployed forces, and its friends and allies.

While endorsing, and in some instances suggesting that DOD's efforts to develop laser weapon systems to defeat ballistic missiles be accelerated, Congress has also expressed concern over the cost and risk associated with developing and demonstrating the maturity of the technologies required to develop such missile defense capabilities.

[2]See Theater Missile Defense: Significant Technical Challenges Face the Airborne Laser Program (GAO/NSIAD-98-37, Oct. 23, 1997) for a discussion of this program.

[3]The Commission was established pursuant to P.L. 104-201, the National Defense Authorization Act for Fiscal Year 1997.

Objectives, Scope, and Methodology

The Ranking Minority Member, Committee on the Budget, and the Ranking Minority Member, Subcommittee on Military Research and Development, Committee on Armed Services, House of Representatives, asked us to review DOD's programs to develop laser weapons for missile defense to

- identify what laser weapons are being considered for missile defense and the coordination among the program offices developing the systems,
- determine the current status and cost of each system, and
- identify the technical challenges each system faces as determined by DOD program managers and analysts and other laser system experts.

To identify the laser weapons being considered for missile defense and what coordination exists among the programs developing the systems, we reviewed DOD budget and Airborne Laser (ABL), Space-Based Laser (SBL), and Tactical High-Energy Laser (THEL) program office documents. We also met with officials of the Office of the Secretary of Defense; the Ballistic Missile Defense Organization, the ABL program office; the Air Force Space and Missile Systems Center; and the Army Space and Missile Defense Command.

To determine the current status and cost of each system, we reviewed and analyzed DOD; Air Force; Army; ABL, SBL, and THEL program offices; and contractor documents regarding the status and cost of the DOD laser weapon programs. We discussed the laser programs with officials of the Ballistic Missile Defense Organization; the ABL program office; the Air Force Space and Missile Systems Center; the Army Space and Missile Defense Command; TRW, Inc.; and Lockheed Martin Corporation.

To determine the technical challenges each system faces, we reviewed and analyzed documents and studies from DOD; Air Force; Army; ABL, SBL, and THEL program offices; and contractors. We discussed the technical aspects of the laser programs with officials of the Office of the Secretary of Defense (Operational Test and Evaluation); the Ballistic Missile Defense Organization; the Air Force Air Combat Command; the Air Force Operational Test and Evaluation Center; the ABL program office; the Air Force Scientific Advisory Board; the Air Force Space and Missile Systems Center; the Army Space and Missile Defense Command; TRW, Inc.; Lockheed Martin Corporation; and Lawrence Livermore National Laboratory.

We conducted our review from November 1997 to December 1998 in accordance with generally accepted government auditing standards.

DOD Developing Three Laser Weapons and Coordinating Its Development Efforts in Various Ways

DOD is developing two laser weapons, ABL and SBL, that are to be used by U.S. forces to destroy enemy ballistic missiles. Additionally, in a joint effort with Israel, DOD is developing the THEL, which is to be used by Israel to defend against short-range rockets.

All three programs have benefited from work performed by the Air Force Research Laboratory on lasers and associated systems. In addition, the program directors for these three programs are coordinating their efforts by meeting periodically to discuss and share information on technology and program development issues. Moreover, some of the same contractors and contractor personnel are involved in all three programs, thereby increasing program coordination.

Developing Three Defensive Laser Weapons

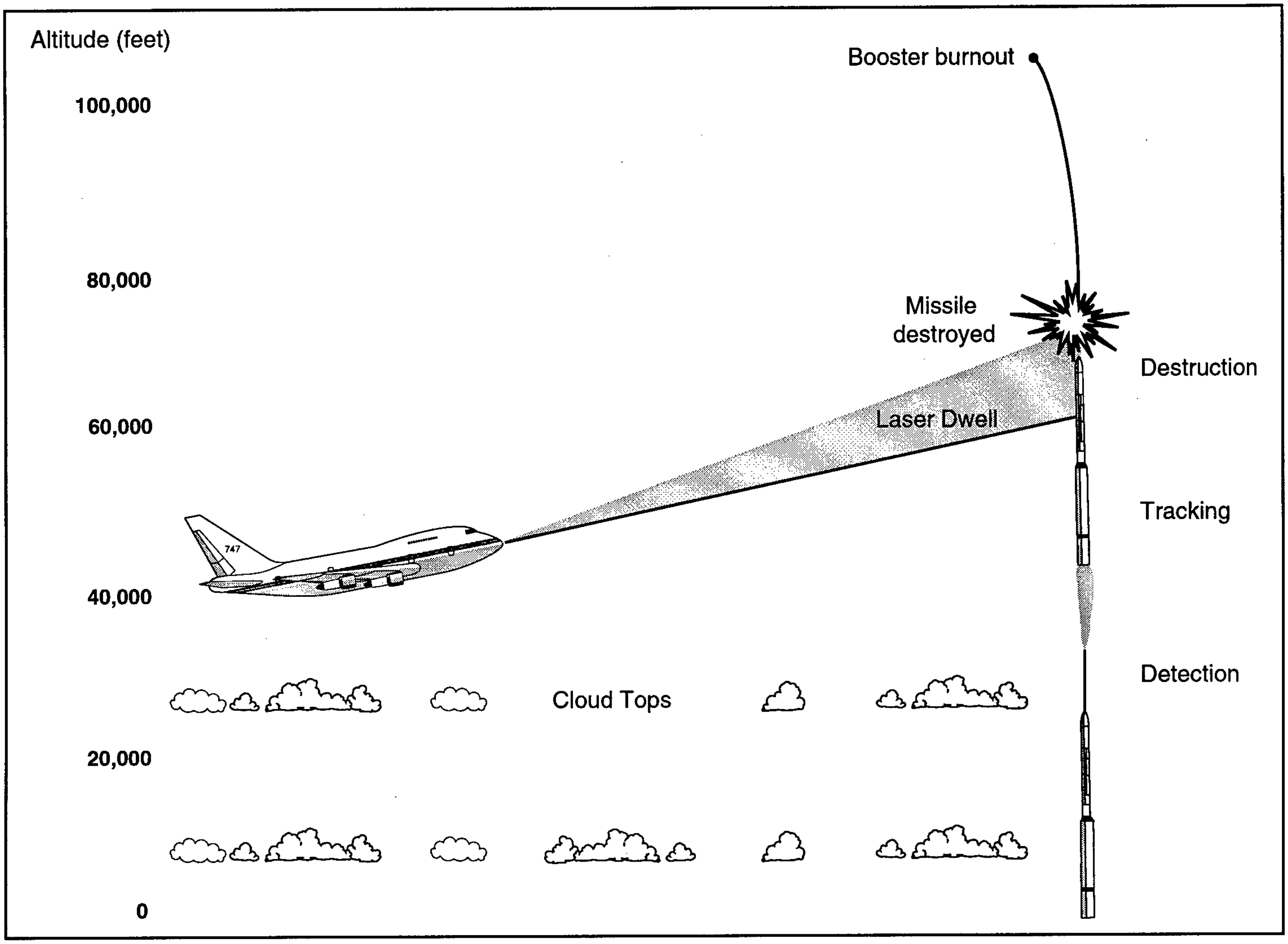
The ABL is to be carried by a 747 aircraft, and the SBL by a constellation of satellites. Both of these weapons are to be used by U.S. forces to destroy ballistic missiles while the missiles are still in the early stage of their flight (boost phase). The THEL is a ground-based laser weapon Israel is to use to defend its northern border cities against Russian-made Katyusha rocket[1] attacks in the final stages of the rockets' flight.

ABL Program

The ABL, funded and managed by the Air Force, is planned to be the first system with the ability to detect and destroy enemy missiles in their boost phase several hundred kilometers away. It is a complex laser weapon system that is being designed to detect an enemy missile shortly after its launch, track the missile's path, and hold a concentrated laser beam on the missile until the beam's heat causes the pressurized missile casing to crack, in turn causing the missile to explode and the warhead to fall to earth well short of its intended target. The program involves placing a multimegawatt laser, beam control system, and related equipment in a Boeing 747-400 freighter aircraft. One prototype ABL is to be produced and tested in 2003 in attempts to shoot down missiles in their boost phase. If this demonstration is successful, the program is scheduled to move into the engineering and manufacturing development phase in 2004. Figure 2.1 shows the ABL concept.

[1]According to THEL program officials, the Katyusha rocket has a range of 8 to 24 kilometers, with a flight time of 20 to 80 seconds. Its boost phase is about 1.5 seconds.

Figure 2.1: ABL Missile Engagement

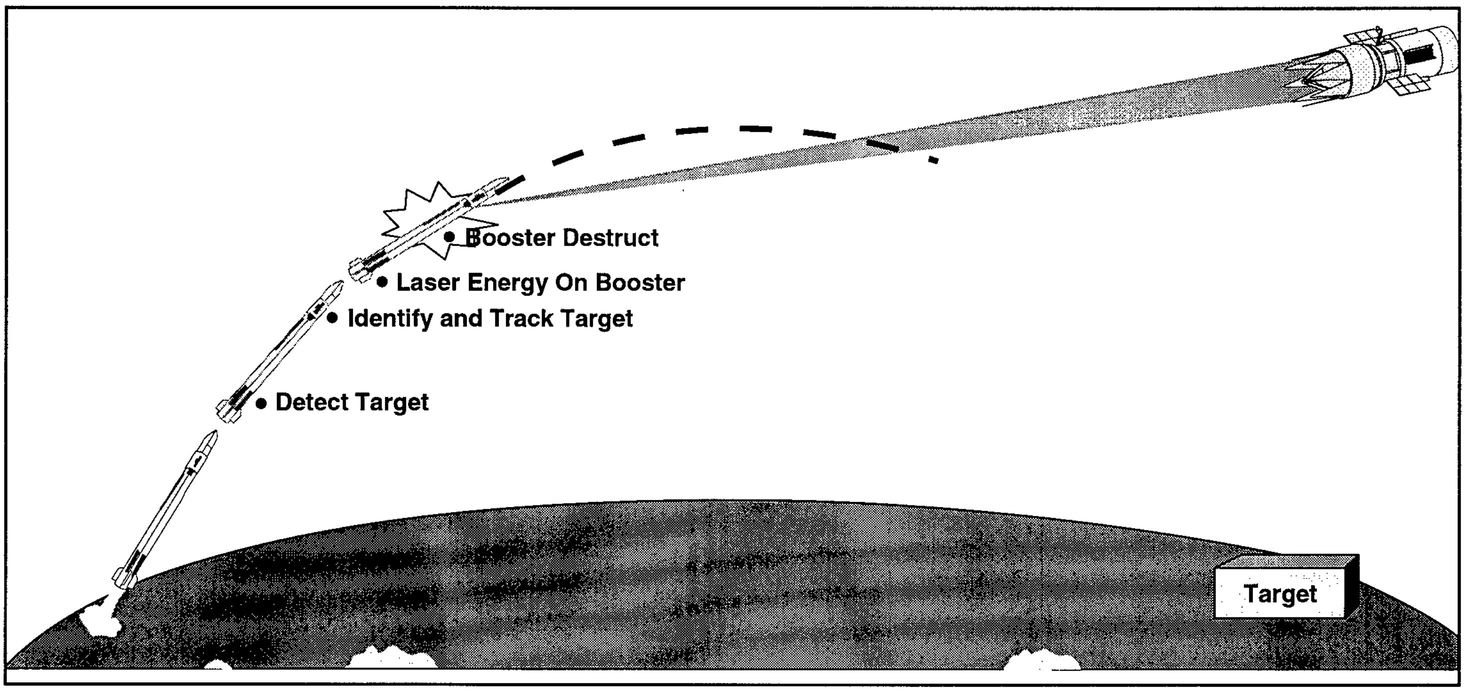


The ABL is expected to operate from a central base in the United States and be available to be deployed worldwide. Ultimately, with a seven-aircraft fleet, five aircraft are expected to be available for operational duty at any given time. The other two aircraft are expected to be undergoing modifications or undergoing maintenance or repair. When the ABLs are deployed, two aircraft are to fly in figure-eight patterns above the clouds at about 40,000 feet. Through in-flight refueling and rotation of aircraft, two ABLs will always be on patrol, thus ensuring 24-hour coverage of potential missile launch sites within the theater of operations. Each ABL is to be capable of destroying about 20 missiles before chemicals needed to generate the laser beam need to be replenished. At that point, the aircraft will have to land to refuel the laser.

SBL Program

The SBL, jointly funded by the Ballistic Missile Defense Organization (BMDO) and the Air Force and managed by the Air Force, is to be capable of detecting a missile in its boost phase, tracking the missile's path, and holding a concentrated laser beam on the missile until the beam's heat causes the missile to be destroyed. The SBL program involves integrating a multimegawatt laser, beam control system, and related equipment on a space platform and launching it into low earth orbit. Air Force estimates show that a full SBL system would not be deployed until after 2020. Figure 2.2 shows a notional SBL engagement.

Figure 2.2: Notional SBL Missile Engagement

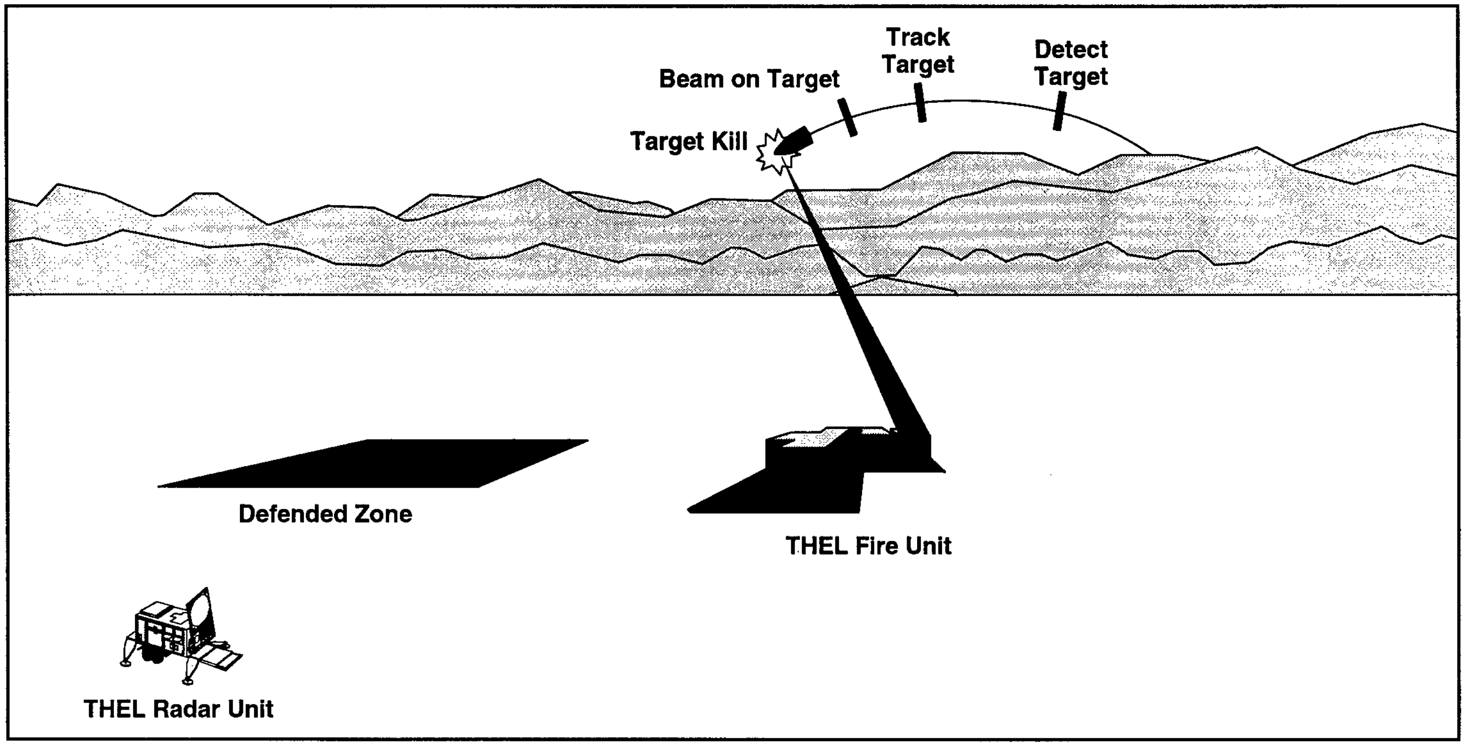


DOD is developing the SBL to provide a continuous global boost phase intercept capability for both theater and national missile defense. The notional concept involves having a constellation of 20 to 35 SBLs. Each SBL is to be capable of destroying about 100 missiles and is to have a range of about 4,300 kilometers.

THEL Program

The THEL, funded jointly with Israel and managed by the U.S. Army, is a ground-based laser weapon that is to be used to destroy short-range rockets toward the end of their flights. THEL is to accomplish this by detecting an incoming rocket shortly after it has been launched, tracking the rocket's path, and holding a concentrated laser beam on the rocket's warhead until the beam's heat causes the warhead to detonate, destroying the rocket. The THEL program involves designing and building a multi-hundred kilowatt chemical laser, a beam control system, a fuel supply system, a laser exhaust system, and other equipment to fit into separate, transportable containers, sized so that each container can be transported by a large truck. The transportable containers are to be placed on concrete pads at deployment sites. Once deployed, the THEL components in each separate container are to be integrated. All THEL components have been produced and are scheduled to be integrated and tested at White Sands Missile Range, New Mexico, in July 1999. Figure 2.3 shows the THEL concept.

Figure 2.3: THEL Rocket Engagement



DOD is developing the THEL, in a joint effort with Israel, to be used by Israel to defend against Russian-made Katyusha rockets and other short-range rockets that have been used by terrorists to attack cities in northern Israel. The number of rockets THEL is capable of destroying is limited only by the amount of laser fuel stored at the deployment site.

Although THEL is a transportable system that can be moved by large trucks, it is not a mobile system, in the sense that the integrated system cannot move under its own power. Because of this limitation, the United States has no use for THEL as it is currently designed. See chapter 5 for additional discussion of the U.S. need for a mobile THEL-type system.

Coordination and Technology Sharing

The three laser weapon development programs have coordinated their efforts by holding periodic program director conferences to share information. In addition, some of the same contractors and contractor personnel are involved in all three programs and all three programs have benefited from work performed by the Air Force Research Laboratory on lasers and associated systems.

According to the program directors of the ABL, SBL, and THEL, they have conducted periodic conferences and frequent phone conversations to discuss and share information on technology and program development issues. They told us that technology developed under one program is shared where appropriate by all programs, thereby reducing duplication. For example, weight reduction techniques developed under the SBL program are to be used on the ABL and THEL programs.

TRW is a subcontractor for the ABL and SBL programs and the prime contractor for the THEL program and is developing the lasers for all three programs. ABL program officials told us that some of the same TRW personnel work on all three programs, thus transferring and sharing their laser technology knowledge between the programs. In another case, the same contractor is to produce the deformable mirrors[2] used in the ABL and SBL programs.

All three programs have benefited from the research carried out by the Air Force Research Laboratory (AFRL). For example, all programs plan to use AFRL-developed optical coatings for beam control and laser optical systems. With these specialized coatings, optics absorb little energy from a high energy laser beam, and heavy, vibration-inducing cooling systems are not needed. AFRL officials have also participated in the three programs in various ways, which enhances information sharing. For example, an AFRL official participating in the ABL program is also acting as a THEL principal on-site government representative.

[2]A deformable mirror is a flexible reflective surface mounted to an array of actuators, or pistons, that can rapidly (up to 1,000 times per second) alter the shape of the mirror. In effect, the mirror's shape is altered to predistort an outgoing laser beam, which is then refocused by the turbulence through which the beam travels on its way to the target.

Airborne Laser: Status, Cost, and Technical Challenges

The ABL program is currently in the program definition and risk reduction (PDRR) acquisition phase.[1] Initial operational capability of three ABLs is scheduled for 2007 and full operational capability of seven ABLs is scheduled for 2009. This schedule reflects a program slip of about 1 year. The Air Force estimates the life-cycle cost of the ABL at about $11 billion.

The ABL program has made progress in addressing some technical challenges, such as atmospheric turbulence that we and others have reported on in the past. However, challenges remain because the components of the system are in various stages of development and have yet to be produced in their final configurations, tested, and integrated into an operational weapon system. Because of the complexity of this integration, some laser experts both inside and outside of DOD have noted that the planned flight testing schedule for the program should be expanded. We believe that the technical complexity of the ABL and related integration issues also raises questions about whether the Air Force's planned ordering of a second aircraft, for modification during the engineering and manufacturing development (EMD) phase of the program, is premature.

Status and Cost of the ABL Program

In November 1996, the Air Force awarded a 77-month PDRR contract to the contractor team of Boeing, TRW, and Lockheed Martin. Under the contract, Boeing is to produce and modify a 747-400 freighter aircraft and integrate the laser and beam control system with the aircraft; TRW is to develop the laser and ground support systems; and Lockheed Martin is to develop the beam control system. The PDRR phase includes two interim milestones--Authority to Proceed 1 (ATP-1), originally scheduled for June 1998, and ATP-2, scheduled for August 2002. The ABL passed ATP-1 in September 1998, 3 months late because the flight-weighted laser module had problems producing the required power level.

The PDRR phase is scheduled to culminate with attempts, in 2003, by the PDRR ABL aircraft to destroy a boosting theater ballistic missile. If these demonstrations are successful, the program is scheduled to move into the engineering and manufacturing development phase in 2004. Initial

[1]This phase consists of steps necessary to verify preliminary design and engineering, build prototypes, accomplish necessary planning, and fully analyze trade-off proposals. The objective is to validate the choice of alternatives and to provide the basis for determining whether to proceed into the next phase (engineering and manufacturing development) of the acquisition process.

operational capability of three ABLs is scheduled for 2007; full operational capability of seven ABLs is scheduled for 2009. This schedule reflects a 1-year slip in the original PDRR schedule. According to the program office, the revision to the schedule is due to a $25-million reduction Congress made in the fiscal year 1999 appropriation for the ABL and to an expanded test program. The Air Force estimates the life-cycle cost of the ABL to be about $11 billion, including $1.6 billion for the PDRR phase, $1.1 billion for the EMD phase, $3.6 billion for the production phase, and $4.6 billion for 20 years of operations and support.

ABL Program Progress

We reported on the ABL program in October 1997. At that time, the immediate area of concern that we and others reported was whether the program had adequately assessed the adverse effects of atmospheric turbulence on the ABL's operational effectiveness.[2] We reported that the Air Force did not have all of the data needed to fully understand the effect that atmospheric turbulence would have on the operation of the ABL and that the Air Force had not determined whether non-optical turbulence measurements could be correlated to optical turbulence measurements.[3] We reported that the Air Force had not shown that it could accurately predict the levels of turbulence the ABL will actually encounter; neither had it shown that the ABL's technical requirement regarding turbulence was appropriate. Consequently, we concluded that it was not yet known whether the ABL would be able to operate effectively in its operational environment. In addition, we reported that the Air Force planned to only take additional non-optical turbulence measurements to predict the severity of the optical turbulence the ABL would encounter without first determining whether the two measurement types could be correlated.

The Air Force has now completed collecting non-optical atmospheric turbulence data from the Korean and Middle East theaters. In commenting on a draft of this report, DOD stated that, while the Air Force's analyses of

[2]The type of turbulence that the ABL will encounter is referred to as optical turbulence. It is caused by temperature variations in the atmosphere. These variations distort and reduce the intensity of the laser beam. Unless these turbulence effects are compensated for, they decrease the laser beam's effective range.

[3]Optical turbulence measurements are taken by instruments that directly measure distortions in light that has traveled from a point source through the atmosphere to the measuring instrument. This can be accomplished by transmitting laser beams from one aircraft to instruments on-board another aircraft at various altitudes and distances, or by focusing on a point source of light, such as a star. Non-optical turbulence measurements are taken by radar or by temperature probes mounted on balloons or on an aircraft's exterior.

these data argue that the design specification established for atmospheric turbulence is generally accurate, the DOD has yet to reach a final position on this issue. DOD stated further that it is still examining the design specification for atmospheric turbulence. According to DOD, the Air Force plans to collect and characterize additional data to further validate its design assumptions. DOD also stated that uncertainties remain concerning the ability to use non-optical turbulence measurements under all conditions to predict operational performance for the ABL. It said that it was considering what additional measurements and analysis are needed to resolve these uncertainties.

The Air Force has also been able to establish that the correlation between non-optical and optical data is adequate for the purposes of estimating ABL performance using non-optical data at this stage of the program. However, according to DOD officials, there are instances where optical and non-optical data disagree and the causes of these differences are not understood. Consequently, the Air Force is continuing to collect and analyze data to further validate its turbulence design assumptions.

Technical Challenges Remain

While the ABL program has made progress in addressing technical challenges relating to atmospheric turbulence, other challenges remain. Developing a laser module that is of the size and weight that can be carried by the ABL aircraft (referred to as a flight-weighted laser module), and integrating the laser, beam control system, and related equipment into an aircraft, are two examples of these challenges.

Flight-Weighted Laser Module Challenges

The technical challenge inherent in the ABL program is exemplified by problems experienced in developing the high-energy laser. The Air Force must build the laser to be able to contend with size and weight restrictions, motion and vibrations, and other factors unique to an aircraft environment, yet be powerful enough to sustain a killing force over a range of hundreds of kilometers. It is also to be constructed in a configuration that links modules together to produce a single high-energy beam. The laser being developed for the PDRR phase will have six modules. The laser for the EMD phase will have 14 modules. When we issued our report on the ABL in 1997, the program had constructed and tested a developmental laser module. Although that developmental module exceeded its energy output requirements, it was too heavy and large to meet integration requirements. It would have to be reduced in width by about one-third and reduced in weight by over one-half. To accomplish this, many components of the module would have to be reconfigured and built of advanced materials, such as composites.

As previously discussed, the PDRR phase of the ABL program includes two milestone decision points--referred to as ATP-1 and ATP-2. To pass ATP-1, the Air Force had to "demonstrate a single laser module at full power with all critical components flight-weighted and show performance (power, beam quality, chemical efficiency, thermal management) is scaleable/ traceable to the EMD design through analysis." During testing of the flight-weighted laser module in connection with the scheduled June 1998 ATP-1 decision point, the module failed to meet its power output requirement. Because of this failure, the program provisionally passed ATP-1.

The program fully passed ATP-1 when, 3 months later, the laser module exceeded its power output requirement by 10 percent. However, the power output was achieved using a flight-weighted laser module that was not representative of the laser modules that will be used in an operational ABL weapon system. Specifically, the flight-weighted laser module used for testing in connection with ATP-1 used a stable resonator. ABL design specifications require that an unstable resonator be used.[4] According to program officials, an unstable resonator is needed because it would produce a laser beam that would allow the ABL's beam control system to focus more of the beam's power on the target than would be possible with a beam produced by a stable resonator. In commenting on a draft of this report, DOD stated that a stable, versus unstable, resonator was used for the initial flight-weighted laser module tests because the test facility had a stable resonator in place, and to replace the stable resonator with an unstable resonator would have been too costly and would have adversely affected the program schedule.

In addition to demonstrating the laser module at full power, ATP-1 also required the program to demonstrate that the beam quality of the laser

[4]A resonator consists of two mirrors placed at opposite ends of a laser cavity. As the reaction of chemicals within the laser cavity produces photons of light, the photons are reflected back and forth between the two mirrors, which causes additional photons to be generated, resulting in a state of high energy within the cavity. In a stable resonator, one mirror is fully reflective while the other is only partially reflective, allowing part of the energy to escape from the laser cavity in the form of a high-energy laser beam. In an unstable resonator, both mirrors are fully reflective but one is much smaller in diameter. As the photons are reflected from the larger mirror in the direction of the smaller mirror, energy escapes from the laser cavity by passing around the edges of the smaller mirror in the form of a high-energy laser beam.

beam generated by the module would meet ABL design requirements. In meeting this requirement, the Air Force did not measure the quality of an actual laser beam generated by the module. Instead, it estimated the beam quality using computer models and measurements of the chemical flows within the laser. In future tests of the laser module, the Air Force plans to measure the beam quality of an actual beam generated by the laser module.

In attempting to demonstrate the laser module at full power, the Air Force identified several design problems. For example, the catch tank and catch tank outlet, which collect and recirculate a chemical used by the laser, were too small. This limited the flow rate of the chemical, reducing the laser's power. Another problem identified was that too much water vapor entered the laser cavity, which reduced the amount of power generated. In addition, gas pressure within the laser cavity was too high, thus slowing the velocity of gases through the cavity, which also reduced the amount of power generated.

Some modifications were made to achieve higher power levels during testing. These and other modifications are currently being finalized and incorporated into the flight-weighted laser module.

System Integration Challenges

The ABL program manager stated that integrating a weapon-level laser, beam control system, and the other related components into an aircraft is the largest challenge facing the program. Some individual components of the ABL have been tested under laboratory conditions and the program office has conducted modeling and computer simulations. However, the individual components have not been integrated and tested as a complete weapon system. As we stated in our October 1997 report, until this system integration and testing is accomplished, it is not possible to predict with any degree of certainty the probability that the ABL program will evolve into a viable missile defense system.

A major aspect of this system integration testing will be the hot fire flight tests when the laser is turned on and the beam is controlled by the beam control system. According to planning documents, hot fire flight testing begins only 4 months prior to the 2003 theater ballistic missile shoot-down tests. Because of the complexity of the system integration task, some experts both inside and outside of DOD have noted that the planned flight testing schedule for the program is too dependent on successful tests and does not allow enough time and resources to deal with potential test failures and to prove the ABL concept.

In a May 1998 Early Operational Assessment, the Air Force Operational Test and Evaluation Center characterized the flight test schedule as "compressed and success-oriented." In addition, the Air Force Scientific Advisory Board, in its February 1998 report, "Airborne Laser Scenarios and Concept of Operations," stated that while the ABL program evolution as currently planned is rational in its sequencing of tests, the schedule appears to have an unrealistically brief flight testing phase. The Board characterized the flight test program as "immature" and said that it needs to be structured to build high confidence in the operability of the laser system. It further stated that past experience with high-power laser systems and large beam directors suggests that new and difficult problems will surface in that phase, and that many flights and targets will be needed to sort them out. The Board suggested that the laser should be fired a reasonably large number of times (in the hundreds) with the ABL in flight before committing to a lethality demonstration and that this would serve to gain experience; establish that it is safe, reliable, and routine; and measure the critical parameters that will give a commander the confidence to use the system without hesitation. Consequently, the Board advised the Air Force to develop contingency plans to prepare for the possibility that the current success-oriented schedule is not achieved, to include ordering additional long lead targets if required, the identification of potential avenues of failure during the flight tests, and preparation of work-arounds or corrective steps prepared in advance.

Congress has also raised concerns related to this issue. The conference report on the Strom Thurmond National Defense Authorization Act for Fiscal Year 1999 noted that the conferees are concerned that the Air Force plans to enter EMD without adequate time to operate, test, and evaluate the PDRR configuration. As a result, the conferees directed the Secretary of Defense to establish an independent review team to assist with the Secretary's evaluation of the technical risk in the ABL program and his determination of whether (1) additional testing and risk reduction is necessary prior to integration of the ABL subsystems into a commercial 747-400F aircraft and (2) the fully integrated PDRR aircraft should be operated for a period of time and thoroughly tested prior to finalizing an objective design. The act directed the Secretary of Defense to report the findings of his assessment of the ABL program by March 15, 1999.

Planned Ordering of the EMD Aircraft May Be Premature

The technical complexity of the ABL and related integration issues raise questions about when a second aircraft, for modification during the EMD phase, should be ordered. Current program plans call for an aircraft to be ordered about 1 year before the planned attempts to shoot down a theater missile with the PDRR aircraft.

The Air Force has a contract with Boeing for the aircraft that will be used during the PDRR phase. According to ABL acquisition plans, a second 747-400 freighter will be ordered in September 2002 for the EMD phase.[5] The ordering of the aircraft is to immediately follow the August 2002 ATP-2 meeting. However, this acquisition strategy will result in the second aircraft being ordered about 1 year prior to the scheduled demonstration of the ABL's ability to shoot down a theater ballistic missile.

Conclusions

The ABL program has made progress in addressing some technical challenges, such as atmospheric turbulence, that we and others have reported on in the past. However, challenges will continue through the development program and we have concerns about some Air Force statements of program successes–specifically, statements related to the power output and beam quality of the flight-weighted laser module. Once these and other problems are resolved, the major program challenge will be to integrate the individual system components into a complete weapon system for testing. A major test for the program will be the flight tests during which the laser is turned on and its beam is controlled by the beam control system. Independent reviews of the ABL program by laser experts indicate that the ABL flight test plan may be too limited and too dependent on successful tests, and not allow enough time and resources to deal with potential test failures and to prove the ABL concept.

The technical complexity of the ABL and related integration issues also raise questions about when a second aircraft, for modification during the EMD phase of the program, should be ordered. Current plans call for the EMD aircraft to be ordered about 1 year before the PDRR aircraft attempts to shoot down theater ballistic missiles. If the PDRR aircraft fails to prove the ABL concept, the funds expended for the EMD aircraft may be wasted.

[5]ABL acquisition plans call for a total of seven aircraft. One ABL is to be produced during the PDRR phase, a second during the EMD phase, and five more are to be developed during the production phase. Also, during the production phase, the aircraft from the PDRR and EMD phases are to be refurbished to production standards.

Recommendation

Regarding the ABL program, we recommend that the Secretary of Defense direct the Secretary of the Air Force to reconsider plans to exercise the option for the second ABL aircraft for the EMD phase of the program before flight testing of the ABL system developed during the PDRR phase has demonstrated that the ABL concept is an achievable, effective combat system.

Agency Comments and Our Evaluation

In a draft of this report, we recommended that the Secretary of Defense direct the Secretary of the Air Force to provide DOD an assessment of the need to expand the ABL flight test program. In commenting on that draft report, DOD partially concurred with our recommendation and stated that its ongoing assessment of the ABL program by an Independent Assessment Team (IAT) would constitute an appropriate assessment of the flight test program.[6]

Subsequent to DOD's comments on our draft report, DOD completed its assessment of the ABL program and reported the results to Congress in March 1999. In its report, DOD noted the IAT's agreement with Air Force plans to restructure the ABL program to expand testing and risk reduction activities before starting modifications to the PDRR aircraft (the first aircraft). DOD concurred with the IAT's recommendation for more testing of the PDRR aircraft before Milestone II, which governs entry into engineering and manufacturing development. DOD stated that it will review the Air Force's proposed restructured program and set a new Acquisition Program Baseline in the spring of 1999. During the restructuring and rebaselining effort, DOD stated that, among other things, it will revise the exit criteria for Milestone II to require more testing against threat-representative targets.

DOD stated that it expects that adding flight tests to the program before the start of EMD will increase near-term costs and might delay ABL's achievement of an initial operational capability. However, according to DOD, the added tests will ensure that the expenditures required for ABL's EMD phase are justified.

[6] This assessment was required by the Strom Thurmond National Defense Authorization Act for Fiscal Year 1999.

We agree with DOD's assessment and future plans for the ABL program. Therefore, we deleted from our final report the recommendation for an assessment of the ABL flight test program.

Based on DOD's comments on our draft report that DOD would not necessarily incur unnecessary costs by proceeding with the purchase of a second ABL aircraft, we revised our recommendation to reflect the need for DOD to reconsider its planned purchase in light of the IAT's findings and our report.

We recognize that delaying the procurement of the aircraft for the EMD portion of the program until after the ABL demonstrates it can shoot down target missiles might require a change in the scheduled initial operational capability. However, such a slip would ensure that the procurement of the EMD aircraft would then be based on the additional knowledge gained in the shoot down demonstrations that the ABL design is feasible. Our recommended approach is consistent with DOD's March 1999 report to Congress on the ABL program wherein it accepted a potential delay in the ABL's initial operational capability in favor of obtaining additional data through increased flight tests. Our approach is also appropriate in view of the discussion in DOD's March 1999 report on the impact of turbulence on the ABL design specification. DOD stated that optical turbulence in excess of the design specification along the slant path between the ABL and its target can reduce ABL's maximum lethal range and increase required dwell times, even at lesser ranges. It said that some analyses of atmospheric turbulence data collected in theaters of interest to date suggest that turbulence levels well above assumed ABL design levels might occur more often than expected at the time the design levels were set. According to DOD, there are currently no clear methods for predicting the actual turbulence level along a slant path to a particular threat location at a given point in time. Thus, according to DOD, beyond trial and error, it is not clear how a correct decision can be made on whether a particular target can be successfully engaged when launched near ABL's maximum lethal range. The Air Force is analyzing turbulence data and investigating tactical decision aids for the system to address this issue.

Space-Based Laser: Status, Cost, and Technical Challenges

The SBL program is about a year into a $30-million study phase to define concepts for the design, development, and deployment of an SBL proof of concept demonstrator. According to the program office, the SBL demonstrator would be the most technically complex spacecraft the United States has ever built. DOD is currently considering an acquisition strategy under which the demonstrator spacecraft would be launched in the 2010 to 2012 time frame. Congress, however, has directed that the demonstrator be launched in the 2006 to 2008 time frame.

Status, Cost, and Technical Challenges

According to a senior SBL program official, the SBL readiness demonstrator will be the most complex spacecraft the United States has ever built. He also said that there is only a 50-percent chance that it will be built and deployed by 2008. According to SBL program officials, the weight and size constraints dictated by the size and weight limitations of existing and planned launch vehicles force the program to push the state of the art in areas such as laser efficiency, laser brightness, and deployable optics. DOD's programmed funding for SBL from fiscal year 1998 to 2005 totals $1.1 billion. DOD officials told us that the design, development, and deployment of an SBL readiness demonstrator would cost about $3 billion.

The conference report for the fiscal year 1998 National Defense Authorization Act states that the Secretary of Defense, in an August 1997 letter to the Senate Majority Leader, confirmed that SBL technology had reached a level of maturity that could lead to a future space demonstration of a sub-scale vehicle. Consequently, the conferees directed the Air Force to promptly establish a baseline for a Space-Based Laser Readiness Demonstrator (SBLRD) to include a set of technical objectives and requirements, a contracting strategy, a system design, a program schedule, and a funding profile that would support a launch in fiscal year 2005. Further, to ensure the focus of the program remains on a fiscal year 2005 (this deployment date was later changed to the 2006-2008 time frame) launch, the conferees directed that they be consulted prior to planned variances from this launch date. In addition, the conferees directed the Secretary of Defense to report on the status of the SBL readiness demonstrator baseline and related issues to the congressional defense committees by March 1, 1998. To date, DOD has not submitted its SBL baseline report to Congress.

In February 1998, the Air Force awarded two 6-month concept definition study contracts, valued at $10 million each, to Lockheed Martin and TRW as an initial step to develop SBLRD. The contractors were tasked to evaluate three strategies:

- a 2005/2006 launch of the SBLRD with existing technology,
- a 2008 launch with existing technology, and
- a 2008 launch infusing advanced technology.

In early 1998, the Air Force's acquisition strategy was to use evaluation data from these two efforts, along with other appropriate data, to award a contract in August 1998 to develop the SBLRD. The objectives of the demonstration would be to validate the SBL as a viable option for missile defense by demonstrating SBL technology readiness and to obtain performance and operations data regarding high-power space lasers, long-range precision pointing, adjunct missions feasibility, and to explore battle management issues.

When the initial acquisition strategy was provided to the Under Secretary of Defense for Acquisition and Technology in August 1998, the Under Secretary was concerned that the strategy focused only on the demonstrator and wanted to know whether the long-term program to develop and deploy the SBL would be affordable. Consequently, he directed the BMDO and the Air Force to restructure and expand the scope of the readiness demonstrator acquisition strategy to include the complete development and deployment of an SBL system. The restructuring was also to include review and assessment of other missile defense concepts such as ground-based lasers and space-based relay mirrors. In addition, the Under Secretary directed them to look for opportunities to develop technologies that would increase the affordability of the SBL by collaborating with other agencies such as the National Aeronautics and Space Administration, which is currently developing deployable optics for its next generation space telescope. In implementing this direction, BMDO and the Air Force restructured the acquisition strategy and extended the concept definition study contracts at a cost of $5 million each. In February 1999, BMDO and the Air Force announced the award of a contract for a joint venture among Boeing, Lockheed Martin, and TRW for $125 million for initiating the Space-Based Laser Integrated Flight Experiment effort that is to result in deploying the readiness demonstrator in the 2010 to 2012 time frame. According to BMDO officials, a full SBL system would not be deployed until after 2020.

The restructured strategy has not received final approval by DOD and is not consistent with Congress' direction to launch the SBL readiness demonstrator in the 2006 to 2008 time frame. In the conference report for the fiscal year 1999 DOD Authorization Act, the conferees expressed concern over the lack of progress in awarding a contract for the readiness demonstrator and directed the Secretary of Defense to promptly release the request for proposals for the SBL readiness demonstrator. At the time of our review, BMDO officials did not know when or if the proposed restructured acquisition strategy will be approved and ultimately submitted to Congress

Conclusions

The future of the SBL program is unknown at this time. DOD is currently doing a comprehensive assessment of the program. That assessment will include alternative ballistic missile defense concepts, such as ground-based lasers and space-based relay mirrors. If, based on this assessment, the SBL is ultimately selected, DOD estimates that a fully operational system would not be deployed until after 2020. Accelerating the deployment date would require the maturation of some complex technologies such as deployable optics and would require a large, but yet unknown, infusion of funds into the program.

Tactical High Energy Laser: Status, Cost, and Technical Challenges

The THEL is about 34 months into its $131.5 million 38-month development program. All of its components--such as the laser, the pointer tracker, and the pressure recovery system--have been built and are currently being tested. The system was scheduled to be integrated, tested, and ready to begin shoot-down tests against short-range rockets at White Sands Missile Range by December 1998. However, the shoot-down testing has been delayed 7 months due to administrative issues and technical problems with the laser and the pointer tracker.

Although THEL's components have been produced, the technical challenges relating to testing and integration remain to be overcome. Initial testing of the laser has identified a problem with the chemical flow control valves. In addition, tests of the pointer tracker have identified problems with the low-power laser that is to track short-range rockets. Furthermore, integration and related testing have yet to begin.

Status and Cost of the THEL Program

In May 1995, a predecessor program to THEL, Nautilus, was started. Nautilus was a joint U.S.-Israel program to evaluate the effectiveness of lasers for potential use as a tactical air defense system against short-range rockets in a variety of missions, including peace-keeping operations. The U.S. Army Space and Missile Defense Command (SMDC), then called the Space and Strategic Defense Command, provided primary management functions for the program. The Israel Ministry of Defense provided support to SMDC. In February 1996, the Nautilus program culminated in a successful test at the Army's High Energy Laser Systems Test Facility (HELSTF) at White Sands Missile Range, New Mexico, using the Mid-Infrared Advanced Chemical Laser and Sea Lite Beam Director to engage and destroy a short-range Katyusha rocket.

In April 1996, President Clinton met with Israel's then Prime Minister Shimon Peres. At the meeting, the United States made a commitment to assist Israel to develop a Tactical High Energy Laser Advanced Concept Technology Demonstrator. This commitment, based on the success of the Nautilus program, was designed to help Israel defend its northern cities from the threat posed by Katyusha and other short-range rockets.

In May 1996, TRW was awarded a contract for $89 million to design, fabricate, and test a tactical-sized deuterium fluoride chemical laser capable of defeating short-range artillery rockets. The original contract called for about a 22-month effort to design and build the system by March 1998. Israel contributed $24.7 million toward the contract cost and developed components such as the fire control radar system, laser fluid supply system, and pressure recovery system (laser exhaust system). In January 1998, the contract was modified to increase its value by $42.5 million to $131.5 million (increasing the U. S. contribution to $106.8 million) and to extend the completion date by 11 months to February 1999 for integration and rocket shoot-down testing at HELSTF. This testing was scheduled to begin in December 1998. However, testing of the laser and the pointer tracker has revealed problems that have, along with administrative issues associated with contract initiation, caused the schedule to be delayed by 7 months, to July 1999.

Technical Challenges Facing the THEL Program

THEL's components have been produced. However, initial testing of the laser has identified problems with the operation of chemical flow control valves and with the low-power laser that is to be used in tracking the short-range rockets.

The initial tests of the laser revealed leaks in the specialized valves that control the flow of chemicals through the laser. These leaks must be corrected because they would detract from the performance of the laser. In addition, testing of the pointer tracker system disclosed a problem with the low-power laser that is to be used in tracking incoming short-range rockets. This laser is a commercial off-the-shelf item that is generally used in laboratory settings. It has been modified for use on the THEL; however, it is still undergoing tests to ensure it meets performance requirements.

The valve leaks and the problems with the low-power laser in the pointer tracker system have caused a delay in the THEL test schedule. Originally, the THEL system was scheduled to be a fully integrated system that would attempt to shoot-down a Katyusha rocket at HELSTF in December 1998. Because of these unanticipated problems and administrative issues, the schedule has slipped by 7 months, to July 1999.

A U.S. Requirement for THEL-Type System Would Present Additional Technical Challenges

Currently, U.S. forces do not have a validated mission requirement for the THEL as it is being designed for Israel.[1] However, the Army has prepared a draft mission needs statement for a reconfigured mobile laser weapon that could be used by U.S. forces to shoot down a variety of targets in theater environments. A THEL official told us that the draft Army mission needs statement is being incorporated into Atlantic Command's Joint Theater and Missile Defense mission needs statement, which includes the need for a mobile high-energy laser weapon.

The THEL would have to be radically modified for it to be more powerful and mobile and thus meet emerging U.S. theater defense requirements for a ground-based laser. While the THEL system being developed for Israel is designed to be transportable, it will not be mobile; THEL components must be transported by large trucks and placed on prepared concrete sites. According to laser experts at Lawrence Livermore National Laboratory, a mobile, ground-based high-energy laser weapon for U.S. use would probably necessitate using a relatively small solid-state laser (versus the much larger and heavier chemical laser being developed for the THEL), the technology for which is relatively immature. The experts said that a generation of solid-state laser research and development would be needed to develop technology to the level necessary for use in a mobile THEL-type system. A program official said that such a system would probably not be fielded until at least 2025. In commenting on a draft of this report, DOD stated that the Army is investigating four solid-state laser concepts and the availability dates and concepts may be different than the assessment provided by Lawrence Livermore National Laboratory officials.

Conclusions

Of the three laser weapon systems that DOD is developing for use against theater ballistic missiles or short-range artillery rockets, the THEL is closest to becoming a fielded system. It is being developed in a relatively short time frame at a relatively low cost. Because THEL is a follow-on to an earlier laser weapon program, its successful development and fielding have been considered relatively low risk. However, technical problems and their associated program delays demonstrate the complex nature of developing laser weapons of this type. Lessons learned from the THEL

[1]The Navy has expressed interest in a THEL-type system for shipboard defenses, but does not have any major efforts planned in this area yet. In addition, the Commander in Chief, Korea, is looking at a THEL-type system for a counter-artillery role. Specifically, he is interested in using a laser weapon to help protect major assets in or near Seoul from enemy rocket attacks.

program will be beneficial if the United States decides to develop a THEL-type system for its military forces. However, given the more demanding requirements that the U.S. will likely have, eventual success of the THEL program will not easily translate into a low-risk, problem-free U.S. program.

Appendix I

Comments From the Department of Defense

OFFICE OF THE UNDER SECRETARY OF DEFENSE

3000 DEFENSE PENTAGON
WASHINGTON, DC 20301-3000

ACQUISITION AND TECHNOLOGY

18 [illegible] 1999

Mr. Louis J. Rodrigues
Director, Defense Acquisition Issues
National Security and International Affairs Division
U.S. General Accounting Office
Washington, D.C. 20548

Dear Mr. Rodrigues:

See comment 1.

This is the Department of Defense (DoD) response to the General Accounting Office (GAO) draft report, "THEATER MISSILE DEFENSE: DOD Efforts to Develop Laser Weapons for Use Against Ballistic Missiles," dated January 19, 1999 (GAO Code 707317/OSD Case 1737). The report treats the Airborne Laser (ABL), Space Based Laser (SBL), and Tactical High Energy Laser (THEL) programs.

The Department partially concurs with the draft report's recommendation calling for a review of the ABL flight test program, with comments in the enclosure. The Department non-concurs with the draft report's recommendation to delay contracting for a second ABL aircraft for Engineering and Manufacturing Development (EMD) until after operational flight testing of the Program Definition and Risk Reduction (PDRR) aircraft, for reasons given in the enclosure.

See comment 2.

See comment 3.

See comment 4.

See cimment 5.

The draft report associates the terms "operational flight testing" and "combat system" to the ABL PDRR aircraft. This is erroneous; ABL operational tests assessing combat capability will use the EMD aircraft. The draft report describes the proposed SBL demonstrator as a weapon system. This is at variance with Department policy; SBL is an experimental program. The draft report miscasts THEL as a ballistic missile defense system. THEL is intended to counter short-range, unguided rocket-propelled artillery in the terminal phase, not ballistic missiles. Finally, the draft report finds that atmospheric turbulence data and analyses presented to the GAO by the Air Force show that the ABL turbulence design specification is generally accurate. The Department has not reached a final position on this matter. The Air Force plans to collect and characterize additional data to further validate its design assumptions, and the Department regards its planned expenditures in this area as prudent. The Department urges the GAO to incorporate these comments on the draft report, and our detailed technical comments provided separately, into the final report.

The Department appreciates the opportunity to comment on the draft report.

Sincerely,

George R. Schneiter
Director
Strategic and Tactical Systems

Enclosure

GAO DRAFT REPORT, DATED JANUARY 19, 1999
(GAO CODE 707317/OSD CASE 1737).

"THEATER MISSILE DEFENSE: DOD EFFORTS TO DEVELOP LASER WEAPONS FOR USE AGAINST BALLISTIC MISSILES,"

DOD COMMENTS ON THE GAO RECOMMENDATIONS

See comment 1.

RECOMMENDATION 1: Regarding the Airborne Laser (ABL) program, in light of congressional, DoD, and Air Force concerns that the ABL flight test schedule is overly optimistic, the GAO recommended that the Secretary of Defense direct the Secretary of the Air Force to provide DoD an assessment of the need to expand the flight test program. (p.8, p.30 / GAO Draft Report)

See comment 1.

DOD RESPONSE: Partially Concur. The Department believes its ongoing assessment of the ABL program directed by the Strom Thurmond National Defense Authorization Act for FY99 will constitute an appropriate assessment of the flight test program. The Act directed the Secretary of Defense to establish an independent team of experts from outside the DoD to assess the program, including the adequacy of exit criteria for its program definition and risk reduction phase. The Secretary's report on the assessment is due to Congress by March 15, 1999.

Now on pp. 8 and 30.

RECOMMENDATION 2: Due to the remaining technical challenges that the Air Force must overcome, the GAO recommended that the Secretary of Defense direct the Secretary of the Air Force to not contract for the second ABL aircraft for the Engineering and Manufacturing Development (EMD) phase of the program until operational flight testing of the ABL system developed during the program definition and risk reduction (PDRR) phase has demonstrated that the ABL concept is an achievable, effective combat system. (pp. 8-9, pp. 30-31 / GAO Draft Report)

See comment 6.

DOD RESPONSE: Non-Concur. In the approved ABL acquisition strategy, the Air Force will order the EMD aircraft in advance of EMD, after conducting an Authority-to-Proceed-2 review of the program. The Air Force will not make irreversible ABL-specific modifications to the EMD aircraft until successful PDRR flight testing supports an EMD (Milestone II) decision. The Department regards this as an efficient, and prudent, acquisition strategy. Purchase of a commercial 747 freighter aircraft is an 18-24 month process. Adoption of this recommendation would delay the achievement of an initial operational capability by 18-24 months and increase costs commensurately. If the Department terminates or delays ABL after ATP-2 but before Milestone II, the Air Force can sell its place in the production queue to another customer or sell the aircraft after delivery, thereby recouping most, if not all, of the money spent on the aircraft. Alternatively, the Air Force could take delivery and store the aircraft until successfully passing into EMD.

The following are GAO's comments on the Department of Defense's (DOD) letter dated February 19, 1999.

GAO Comments

1. The Secretary of Defense submitted his report on the Airborne Laser (ABL) program to Congress in March 1999, subsequent to DOD providing comments on a draft of this report. The Secretary reported that the ABL flight-test program will be expanded. Since this action is consistent with the recommendation in our draft report, we have deleted the recommendation from the final report.

2. We agree that operational testing for the ABL program will not begin until the engineering and manufacturing development (EMD) phase and have modified the text by deleting the word operational. However, we retained the term combat system because it refers to the ABL concept and not to the program definition and risk reduction (PDRR) aircraft.

3. We have modified the report to clarify that the Space-Based Laser (SBL) is a demonstration program.

4. We have modified the report title and text to clarify that the Tactical High-Energy Laser (THEL) is not a theater ballistic missile defense system.

5. We have modified the text of the report to reflect that DOD has not yet reached a final position on the issue of atmospheric turbulence.

6. We did not assess the marketability of the 747 freighter aircraft by the Air Force if it decides to terminate or delay the ABL program. However, if after ordering the aircraft DOD decides to terminate the program, it would be liable for up to $50 million unless it can successfully sell its place in the production queue or sell the aircraft. DOD did not include in its comments an estimate to store the aircraft if the ABL program is delayed.

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