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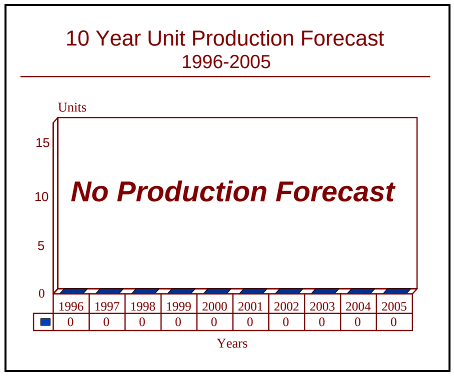
BMD Laser Radar - Archived 10/97

Outlook

- Program terminated in 1993
- This laser technology likely to gain renewed support in light of recent successes of other BMD programs



Orientation

Description. The purpose of this project is to develop laser radar systems, components and architectures capable of supporting Ballistic Missile Defense (BMD) requirements. (BMD was formerly known as the Strategic Defense Initiative (SDI) prior to May 1993.)

Sponsor

US Army
Strategic Defense Command
Huntsville, Alabama (AL)
USA
(Program manager)

US Air Force
Rome Air Development Center
Griffiss AFB
Rome, New York (NY)
USA
(Support technology)

Weapons Laboratory
Kirtland Air Force Base, New Mexico (NM)
USA
(Manager for laser mirrors)

Contractors

Avco Systems
Textron Defense Systems
201 Lowell Street
Wilmington, Massachusetts (MA) 01887
USA
Tel: +1 508 657 5111
Fax: +1 508 657 2138
(Laser imager component development)

Hughes Aircraft Co
Aerospace and Defense Sector
7300 Hughes Terrace
PO Box 80028
Los Angeles, California (CA) 90080-0028
USA
Tel: +1 310 568 7860
Fax: +1 310 568 6715
(Low-weight space-based laser radar)

McDonnell Douglas Aerospace
5301 Bolsa Avenue
Huntington Beach, California (CA) 92647
USA
Tel: +1 710 896 3311
Fax: +1 710 896 1308
(Laser radar for STM mission)

Photonic Systems
Melbourne, Florida (FL)
USA
(Laser radar image processor)

Stanford Research Institute
333 Ravenswood Park Avenue
Menlo Park, California (CA) 94025-3493
USA
Tel: +1 415 326 6200
Fax: +1 415 326 5512
(Study of laser radar detection uses)

Bell Helicopter
PO Box 482
Fort Worth, Texas (TX) 76101
USA
Tel: +1 817 280 2011
Fax: +1 817 280 3631
(Chemical laser radars for BMD)

Status. Program terminated in FY93.

Total Produced. Engineering developmental models only.

Application. The Ballistic Missile Defense Organization (BMDO) had hoped to develop imaging optical lasers capable of providing very accurate range and target configuration data. Imaging lasers also have the potential to provide superior chaff discrimination compared to radar sensors. In addition to mid-course target ranging/discrimination applications, the BMDO's kinetic energy weapons office also considered the use of laser radars for space-based interceptor (SBI) fire control.

Price Range. Indeterminate due to the developmental nature of the program.

Technical Data

Design Features. Starting in FY91, this project was divided into two segments which appeared as separately funded DoD budget program elements; Ladar Engineering and Ladar Technology.

Ladar Engineering. This segment supported the SDI Phase 1 Defenses program element and focused on the development of laser radar systems, components and architectures that could provide an early deployment option against limited attacks and for providing low-to-moderate defensive capabilities against a then envisioned large-scale ballistic missile attack on the US. The development of systems and components emphasized fieldability issues such as weight and volume reduction, efficiency enhancement, producibility, survivability and cost for GPALS (Global Protection Against Limited Strikes) elements funded under the Phase 1 Defenses effort. Laboratory and field measurements supporting system design and validating system concepts and effectiveness were scheduled to be performed. The emphasis was on technologies supporting precision bus tracking, threat tube definition, and impact point prediction. Specific technical developments included short wavelength laser radar transmitters (such as excimer and solid-state), receivers, and rapid retargeting beam steering and receiving systems.

Ladar Technology. This program element supported the Follow-On Systems program element and focused on the development and demonstration of laser radar technologies that are capable of supporting Strategic Defense System components and architectures for applications and deployment in the next century. Work under this effort included the development of components, systems, databases of target measurements, and supporting analysis. Component development efforts included laser transmitters, receivers, mechanisms for steering and directing beams, and signal processing. Database developments included both laboratory and field measurements, and the development of simulations for calculating laser radar cross sections and evaluating system performance.

Laser radars are preferable over microwave radars in many applications because of ladar's smaller size and tighter beam divergence, as well as the fact that ladars also provide the spatial and velocity resolution for midcourse discrimination of reentry vehicles from other objects. Ladar technology can also be effectively applied to the boost phase intercept of threat missiles by the active tracking of these missiles and precision pointing of boost-phase weapons. Specific technologies addressed in this program element included lasers with high temporal and frequency stability and wide bandwidth, wide bandwidth detectors, optical beam steering and receiving systems for rapid retargeting, and signal processing and analytical tools required for implementation.

The US Army Missile Optical Range was used to make calibrated laboratory target measurements. The Firepond ladar was also used to make field measurements of deployment events of targets launched from Wallops Island, VA. The Firepond ladar demonstrated conclusively in 1990 the utility of the use of imaging ladars for measuring target dynamics and performing a credible discrimination role at the ranges required for strategic defense systems.

Additional accomplishments under this initiative included the enhancement of the CO_2 laser target measurement database by extending calibrated laboratory measurements to over 21 target signatures, and the validation of the defense laser/target signature code. Concomitant component development effort accomplishments included significant progress in both ladar transmitter (demonstration of a transmitter architecture with the potential for significant weight reduction and capacity for producing the required output energy for long-range imaging applications) and beam control technology (demonstration of an innovative, lightweight, mechanical system able to integrate 50 targets per second). Progress achieved in ladar technology permitted ladar to be incorporated into the Brilliant Eyes concept in the reformatted Strategic Defense System.

Variants/Upgrades

This is a technology development program characterized by the evolutionary definition of the system. By its nature, it consists of a continuing series of variants and upgrades.

Program Review

Background. Prior to the creation of the Strategic Defense Initiative (SDI), the Army Ballistic Missile Defense Systems Command (now known as the Army Strategic Defense Command) had been involved in advancing the state-of-the-art in multiple detection and discrimination technologies through component /subsystem fabrication and demonstration. It planned to develop and validate technology and concepts to provide the US Ballistic Missile Defense (BMD) system with technical options and assist in the refinement of US strategic offensive force capability.

In FY80, the Bell Helicopters Division of Textron Inc (Fort Worth, TX) received a US$110,000 contract for research on a chemical laser radar for BMD. The Army's BMD center had previously investigated a wide range of novel technologies applicable to the missile defense role. The program examined a variety of laser radar and LIDAR techniques and their suitability for that mission. Although heavily classified, the effort apparently was aimed at developing systems to help distinguish between real warheads and penetrating decoy warheads by sensing anomalies in the flight patterns or reentry pattern of the decoys as compared with the real warheads.

In LIDAR (Light Detection and Ranging) Device related developments, the Navy contracted the Stanford Research Institute to conduct a feasibility study of the use of laser radar for the detection and identification of chemical and biological warfare clouds. A prototype system was built for NASA for possible application to satellite-borne atmospheric sounding methods. Further testing of this system was scheduled to be performed on the space shuttle.

Also prior to the formation of the SDI effort, ARPA and the US Air Force worked on a rapid optics fabrication technology (ROFT) program. ROFT was tasked with the goal of producing both high power density optical surfaces for high-power lasers and also large optics for passive infrared surveillance.

In support of the massive SDI effort, in 1984 the Strategic Defense Initiative Office (SDIO) was formed to serve as the administrative agency to consolidate and coordinate the diverse activities previously conducted by other government agencies which had potential application to SDI, and to formulate and direct the overall SDI effort. In that year, the SDIO disclosed that initial efforts in the SDI project included the development of ultra-lightweight optics and an assessment of the procedures needed to produce them. Also, promising computer-controlled, polishing techniques were investigated to scale-up machines capable of working large surfaces. Stable laser oscillator studies were performed which lead to several possible constructions, and different techniques were investigated.

Starting in FY85, the SDIO consolidated efforts within this project which drew on and continued existing technology base activities in areas such as ultra-lightweight, cryogenically cooled optics, multispectral optical detectors, laser devices and pointing/tracking subsystems. Two large, actively controlled, aspheric mirror panels were to be edge-matched and figure-controlled at cryogenic temperatures.

A small number (between two and four) of rapid optics fabrication efforts were selected for demonstration at medium scale. Also, work was initiated to develop appropriate algorithms for this project as it related to optical imaging. The project worked on the technology development needed for improved laser transmitters and imaging sensors. In addition, plans were laid out for future demonstration experiments.

In FY86, the Pentagon focused its rapid optics fabrication efforts on a demonstration at medium scale. The goal of the project was to integrate fundamental technologies and conduct subsystem demonstrations required to make technical feasibility decisions. Initial parallel demonstration efforts were to be down-selected to the engineering development of one or two of the most promising approaches, and data obtained from the measurements program used to verify sensor design parameters. Also in 1986, new laser radar transmitters were designed and, in some cases, fabrication begun. These included high-resolution IR lasers and UV lasers to be used to implement additional discrimination techniques. Laser beam agility techniques were also defined, and some techniques tested at low power levels.

In September 1986, NASA launched a Delta Rocket from Cape Canaveral, FL, as part of the SDIO's "Significant Technical Milestone" experiment to obtain data on the operation of space-based sensors and the infrared signatures of missile plumes. The Delta rocket carried a US$42 million classified payload which consisted of two sensor packages. One cluster of sensors included a laser radar. The space-based laser radar used in the experiment was described by SDIO officials as having an accuracy down to a one degree field of view.

The test of this McDonnell Douglas developed laser radar marked the first time that such a system had been tested in space. Based on the McDonnell Douglas Lasercom Space Measurement Unit (LSMU) adapted to laser radar use, the device was delivered to the Air Force in nine months. Significant software, electronic, and mechanical modifications were made to the original LSMU to adapt it for LIDAR application.

Delphi. An unclassified March 1987 Senate staff report revealed details of a project conducted at the Department of Energy's Sandia Laboratory code-named "Delphi." Delphi, which stands for Discriminating Electrons with Laser Photon Ionization, was described as a pop-up system which would use a laser beam to, in effect, identify and categorize re-entry vehicle decoys.

The Delphi system was identified as having the potential for deployment against high value targets such as its use as a short-range discriminator in the late midcourse and early terminal phases of a ballistic missile trajectory. Delphi would augment the Airborne Optical System, taking up the responsibility to provide threat discrimination as the capability of the airborne passive sensor decreased. The potential utility of Delphi notwithstanding, the Senate report noted that the FY87 budget for Delphi research was cut from US$20 million down to US$6 million. The FY88 budget request for Delphi, according to the Senate study, was US$22 million.

Other Efforts. In August 1987, both NASA and the SDIO expressed an interest in the Alexandrite Laser developed by Allied Signal of Morristown, NJ. This laser possessed the parameters which would support its use in a space-based laser radar for assessing the atmospheric conditions on Earth through which ground-based laser beams would travel.

Also in August 1987, the Naval Research Laboratory, Washington, DC, sought proposals for a basic research effort with the objective of developing techniques and associated advanced hardware for a space-based UV laser radar receiver and imager. Multiple contracts which ran from six months to three years and worth between US$100,000 to US$1 million were anticipated by the Navy.

In February 1988, a second SDI Significant Technical Milestone (STM) experiment, designated the Delta 181 Mission (also known as the "Thrusted Vector" mission, a reference to the sensor module payload carried onboard the Delta rocket) was carried out. The satellite used both passive and active sensors to acquire information on man-made targets and the space environment. Active sensors incorporated in the Delta 181 payload included a pulsed ladar (laser-radar) built by the GTE Government Systems Corp and a coherent Doppler ladar built by Martin Marietta Orlando Aerospace.

PE#0603220C Activity. During the SDI effort, laser radar and related optical tracking technologies appeared as a dedicated DoD project element PE#0603220C: Surveillance, Acquisition, Tracking, and Kill Assessment (SATKA). The project was composed of a number of major task areas designed to perform research on concepts of future electro-optical imaging capabilities. These are summarized below.

Surveillance Large Optics Technology. This project was a comprehensive program of technology developments required to make possible the wide variety of large optics required to implement certain concepts. Technologies were to be developed and demonstrated to allow production of very large, very lightweight, very precise optics. These optics would be required to operate at cryogenic temperatures and have the ability to reject stray radiation even when the source is very close to the target. The requirement was also placed on these optics that they be capable of high rate manufacture in order to support the deployment of a constellation of defense satellites in a timely manner. This project addressed key issues throughout the entire life cycle of a large mirror, from material selection through maintenance of high optical performance after deployment as part of an orbiting surveillance platform. Major research areas in this project included the following: aspherical surfacing, beryllium and ceramic substrates, coatings, contamination control, and survivability support.

Laser Radar Technology. This project developed technologies required for the construction of laser transmitter and receiver components. A vigorous program designed to confirm technical feasibility was formulated with emphasis placed on discrimination. Potential countermeasures were identified and their effectiveness addressed. The Low Weight Kinetic Energy Weapon Active Tracker (LOWKATER) project developed a then state-of-the-art design and initiated construction of a nominal 100-watt, 250-kg, 1.5-cubic-meter CO_2 laser radar system capable of providing excellent range and velocity measurements on small targets located up to 1,000 kilometers away, and for larger targets up to 3,000 kilometers away. The project emphasized the development of diode-pumped slab laser technology, which was to demonstrate a 10-watt system in 1990 and a 100-watt system within two years. The Strategic Laser Technology (SLT) project was dedicated to developing higher-powered CO_2 laser radars for medium earth orbit-based missions. An important part of the SLT project integrated rapid optical beam steering subsystems, such as the Roving Fovea and coherent array concepts, with laser transmitters developed under the SLT project.

Beam Agility. The goal of this project was the development of laser radar systems capable of randomly addressing targets spaced across a wide field of view. Several unique concepts involving phased arrays of optical sub-apertures were analyzed and tested in laboratory experiments, according to the SDIO. During 1988 the Navy demonstrated several techniques at its Naval Weapons Center at China Lake, CA, that satisfied SDI near-term requirements for beam agility. The SDIO also reported in its April 1988 Report to Congress that an alternate concept using a frequency-tunable solid-state laser in conjunction with an optical grating had matured to the point of a low-power laboratory demonstration capable of retargeting times of less than 1 millisecond. An innovative rapid optical beam steering system (Roving Fovea) was developed which would allow one laser radar satellite to view many post-boost vehicles in rapid succession.

Early Demonstration of Angle-Only Tracking. This particular effort was dropped from the project element in FY87. Its purpose was to provide data and explore issues related to midcourse acquisition, tracking, discrimination and designation. According to the SDIO at the time, alternate approaches were continuing to be pursued for this task which was considered still to be in its infancy. A near-term goal of the effort was to demonstrate angle-only tracking from an airplane, with range-tracking capabilities to be demonstrated after that. In an operational system, optical inverse synthetic aperture imagers would be installed on multiple satellite platforms. Using an approximate 13-foot aperture and 100 kilowatts of power, such a system would provide a resolution of 20 centimeters at a range of more than 625 miles. Target distances could be determined to an accuracy of within a few meters according to design studies.

Firepond/LOWKATER. This task provided for the demonstration of the high-power range-Doppler imaging of space targets making use of the MIT/Lincoln Laboratory Firepond facility near Boston, Massachusetts. The Firepond facility provided an advanced CO_2 laser radar system, coupled with existing X- and L-band imaging and tracking radars, for ground-based measurements of discrimination parameters using rocket-launched targets in space.

The LOWKATER program was designed to demonstrate the imaging capabilities of the existing Firepond laser. A fabrication contract was issued in 1989 for demonstrating the ground-based version of Firepond in the 1991/92 time frame. The successful Firepond ladar observation of Firefly sounding rocket experiments in March and October 1990 conclusively demonstrated the utility of ladars for measuring target dynamics and executing a credible discrimination role at the ranges required for strategic defense systems. The Firepond ladar carried out range-Doppler imaging and precision tracking measurements on inflatable decoy targets launched from Wallops Island and viewed at a range of 800 kilometers from Firepond. In addition to providing precision measurements of deployment dynamics and images of a decoy in space, the October Firefly test included precision ranging of a decoy in space using a doubled neodymium solid-state laser similar to that required for the Brilliant Eyes program.

Specific project accomplishments in FY91 included: conduct of the Firebird experiment that investigated effects of plume impingement associated with space deployment from a thrusting bus; and demonstration of the phenomena that objects coated to be low observable at microwave radar frequencies had a high laser radar cross-section. Fabrication of a low-power, transportable laser radar system was also completed.

FY92 work included: completion of the tracking algorithms and testing of the low-power, transportable laser radar system; completion of fabrication and testing of the space traceable CO_2 laser radar system; performance of the Firebird 1b experiment to investigate space deployment phenomena, countermeasure, and discrimination; generation of bistatic target measurements to validate the DELTAS code for this geometry; and the initiation of a program to take measurements at three laser wavelengths at the Army Missile Optical Range.

In FY93 the SDI Laser Radar program was terminated by the Clinton Administration which retitled the SDI program Ballistic Missile Defense (BMD) and shifted emphasis away from space-based laser/radar technology to ground-based radars.

The Firepond system was slated to be packaged for future space experiments; however, those plans were dropped concurrently with the program cancellation. Also axed from the budget were the stable LO, electronically combined array beam steering, and the Maui ladar programs.

In mid-1994 the BMDO, in an attempt to keep SDI technologies alive, selected 94 US businesses for 116 Phase I research awards, averaging approximately US$61,000 each. Research funded by these awards aimed to channel several new related technologies into related government and commercial applications.

Funding

All funding for the SDI-Based Laser radar was canceled beginning in FY93.

Recent Contracts

No contracts have been identified since a 1992 award of $0.8 million to Photonics Systems to develop a laser radar image processor.

Timetable

	FY80	Early contract awards under US Army BMDSC program
	FY84	Start of Imaging Laser Technology (Optical) as SDI initiative
	FY85	AF Weapons Laboratory requested laser mirror production
	FY86	Proposed engineering scaled mock-ups of laser mirrors
Sep	1986	Laser Radar used in Delta 180 test
Feb	1988	Laser Radar tested in Delta 181 mission
	1988	Firepond ground-based laser radar test
	1990	10-watt solid-state laser radar tested
	1992	100-watt solid-state laser radar to be tested
Apr	1992	100-watt CO_2 laser scheduled to be available for full-scale development by this time
May	FY92	Perform Firebird 1b test
	FY92	Completed Transportable Ladar System Testing
	FY92	Initiated 3 Wavelength AMOR measurements
Aug	FY92	Completed space traceable CO_2 transmitter fabrication
	FY93	SDI laser radar program terminated

Worldwide Distribution

This is a **US** program only.

Forecast Rationale

With the election of President Bill Clinton in 1992 and a Democratic administration, interest in the space-based aspects of the Strategic Defense Initiative collapsed. In May 1993, Secretary of Defense Les Aspin announced the retitling of SDI to the Ballistic Missile Defense program to better emphasize the shift in focus to one of ground-based interceptors defending the country from a limited nuclear strike. The SDIO was disbanded, budgets severely cut, and responsibility for the development of a theater ballistic missile defense system assigned to the BMDO. While the foundation upon which the initiative was built has disappeared, strong support remains for a national missile defense system. Such a system has been championed by the now Republican-controlled Congress over the last year, and even for a time part of presidential candidate Bob Dole's election platform. Uncertainty regarding future threats in limited engagements, initiated by leaders such as Saddam Hussein, fueled a surge of interest in fielding such a system as quickly as possible.

The technical emphasis in providing such a system has been placed on ground-based intercept systems using more or less conventional radar tracking and defensive missile interceptors, which are deployed against the threat in the mid- or final phase of an attack. Operational analyses, however, promptly indicate the advantages of a boost phase intercept (BPI) defense, which are achieved by the relaxation of the stringent time-line constraints placed on the acquisition, discrimination, tracking and weapon kill phases of an end-game defense. To be effective, however, the BPI concept requires an airborne/space based reconnaissance/weapons platform. A pivotal element in this type of platform is the imaging laser radar which can be used to provide target acquisition, identification and tracking functions.

While SDI has been canceled, there are several indicators that the advantages of a BPI-based defense, and in particular a laser weapon-based system, have not gone unnoticed. One indicator is the quiet technical progress which has been made in high-energy laser systems in the face of extreme budget constraints. (See separate Airborne Laser Demonstrator and SBL reports in the *Electro-Optical Systems Forecast* binder).

The SDI-originated ladar program was cut at a time when a number of different avenues were being explored to determine the best technological approach for a laser radar. These approaches included high- and low-power, long-wave (CO_2) and short-wave (solid-state) lasers. As the merits of each were explored, a final configuration was in the process of being established. The process had reached the point where CO_2 laser radar systems were generally considered more advanced than the solid-state lasers, but the solid-state systems offered the possibility to provide significant savings in weight, higher efficiency, reduced size of optics and beam control systems, and more rapid beam retargeting capability.

It should be noted that significant progress in ladar technology was realized under the precancellation contract structure. Specifically, the ladar technology advances achieved allowed the laser radar to be incorporated into the Brilliant Eyes concept. A laser radar was also to be incorporated in the USAF Early Airborne Global Launch Evaluation (EAGLE) program.

There is a realistic possibility that a segment of the SDI system, dedicated in this instance to the defense against limited theater missile attacks, will gain congressional support. Due to the key role that a high-performance ladar would play in implementing a system of this type, this report will be maintained even though this particular program has logged no activity for some time. Activity has been progressive in several BMD laser programs over the past year. Plans are under way for an airborne laser demonstration, and support is high for a joint US-Israeli program to develop, test and produce a tactical high energy laser (THEL). This is the Nautilus program, which won credibility through its successful February 1996 testing (in which it intercepted and destroyed a Katusha missile in-flight) as well as the endorsement of President Clinton. The US and Israel have signed an MoU to accelerate work on Nautilus, and a THEL Advanced Concept Technology Demonstration prototype should be built by November of this year (see separate report in this binder). The time may soon be propitious for the BMD Laser Radar to be drawn from behind the scenes and taken to center stage.

Ten-Year Outlook

Not applicable at this time.

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