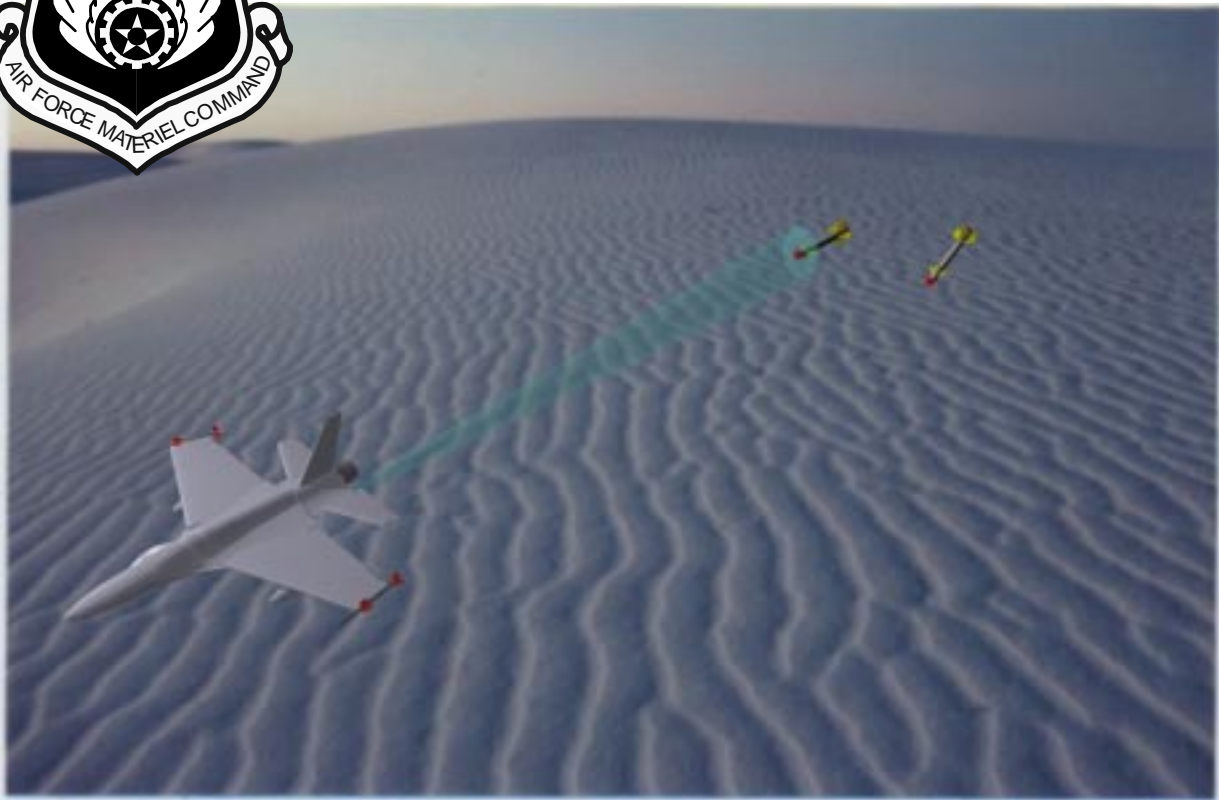


FY98 DIRECTED ENERGY TECHNOLOGY AREA PLAN



**AIR FORCE RESEARCH LABORATORY
WRIGHT PATTERSON AFB, OH**

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Note: This Technology Area Plan (TAP) is a planning document for the FY98-03 S&T program and is based on the President's FY98 Budget Request. It does not reflect the impact of the FY98 Congressional appropriations and FY98-03 budget actions. You should consult PL/XP, DSN 246-4962 or Commercial (505) 846-4962 for specific impacts that the FY98 appropriations may have had with regard to the contents of this particular TAP. This document is current as of 1 June 1997.

DIRECTED ENERGY



VISIONS AND OPPORTUNITIES

The Phillips Laboratory (PL) develops and transitions warfighting technologies in three primary areas: space and missile systems, geophysics, and directed energy.

This Technology Area Plan encompasses the development, demonstration, and transition of Directed Energy technologies; the determination of the susceptibility of USAF systems to similar foreign threats; and the development of protection technology to enhance the survivability of USAF systems. On-going and planned R&D will lead to advanced weapon systems using high energy lasers, high power microwaves, and related capabilities such as high resolution optical imaging. Efforts in survivability assessment and protection technology involve the development of both hardening technology and the criteria for protecting USAF systems against directed energy weapons, and natural and enhanced space radiation.

As the national center of excellence for directed energy, PL is well qualified to provide the technology for tomorrow's warfighters. Directed energy weapons (DEWs) offer the opportunity to leapfrog over incremental advances in conventional weapons by providing revolutionary capabilities for both offense and defense. These

technologies and the advanced weapon systems they make possible are a critical part of the Air Force's "Global Engagement" vision.

Within the Directed Energy Technology Area, PL develops moderate and high power laser devices; highly accurate optical acquisition, tracking, and pointing technology; high resolution optical imaging; moderate and high power Radio Frequency (RF) weapons and countermeasures; and protection technologies. These application technologies are supported by on-going research in pulse power, nonlinear optics, target effects and vulnerability, survivability assessments, and systems performance and mission effectiveness analysis.

After years of investment, laser devices have reached a maturity which supports a clearly defined path to operational systems for both weapon and supporting applications. A realistic example of a weapon system is airborne theater missile defense (TMD) roles. Lightweight, compact, and efficient lasers at moderate power and selected wavelengths also are envisioned for a variety of applications, such as imaging, infrared countermeasures (IRCM), communications, illumination, target designation, special operations and Nuclear

Biological and Chemical (NBC) detection.

The coming decade will see a demonstrated capability in beam control systems. Continued progress in compensating for beam distortions due to atmospheric turbulence will provide enabling technology for long-range laser weapon systems. The proven ability for high accuracy tracking and beam pointing give credibility to the precise application of energy at the speed of light to specific target aim points. With the combination of laser source and beam control technologies, the laser as a viable weapon system will come of age. We fully expect laser systems to proliferate in the Air Force inventory within the next ten years.

Maturing laser source and beam control technology is also the foundation for a revolution in optical imaging technology. Atmospheric compensation and illuminator laser technology, in combination with innovative image sensing and processing concepts, will greatly improve the coverage and resolution of imaging systems. Operational commands will obtain high quality, timely imaging products for applications such as space object identification, long range airborne imaging, and new technology approaches for space-based sensors. These technologies will become the eyes of the future Air Force.

Another promising capability in the coming decade will be the use of High Power Microwave (HPM) technology. HPM will represent a major potential advance in Electronic Warfare technology by extending conventional RF power output several orders of magnitude. This enables the damage and disruption of a broader range of targets and simplifies the threat-specific nature of systems. HPM will be used to attack multiple enemy communications and radar systems, and will be useful as a potential generic countermeasure to a wide range of IR and RF guided weapons. Several advanced technology demonstrations of HPM weapon concepts are planned in coordination with USAF operational users. This electronic sword works both ways, however, and protecting US electronic assets is equally important. This involves not only the careful design of US HPM weapons, but also hardening US assets against potential enemy

HPM and other inadvertent RF threats. PL is at the forefront in developing RF susceptibility measurement and systems hardening technologies for transition to military users and industry. Finally, PL is pursuing advanced pulse power development as a key technology for high power RF sources.

Integral to S&T investment strategy and planning is the development of advanced technologies and tools that assure the operational capabilities and military utility of evolving systems supporting critical mission areas such as Space Control. As we transition from an Air Force to the Air and Space Force of the future, we must provide the technologies and capabilities that provide protection of our space systems from a broad spectrum of potential threats. The importance of protection and the associated element of satellite threat warning and attack reporting is receiving increasingly high levels of visibility as the space architectures of the future are being refined and the systems supporting those architectures are designed, developed, and made operational. PL embodies world-class experimental and computational tools to complete unique survivability and vulnerability assessments of US and foreign space systems, subjected to a wide range of threat environments. Over the next few years PL will continue to integrate the survivability and vulnerability characteristics of additional classes of space systems, with their mission-critical payloads, into modeling and simulation capabilities to predict threat-stressed performance in operational environments. This will lead to the determination of survivability enhancement options, and the development of protection technologies to mitigate performance degradation as a result of natural and enhanced radiation, optical and DEW threats, KEW, and other advanced terrestrial, airborne, and space-based weapons.

PL's vision in directed energy is one of providing major new military capabilities and shaping the nation's defense posture. Talented and dedicated PL professionals along with modern research facilities stand ready to meet the challenge of military superiority in the next century.

This plan has been reviewed by all Air Force laboratory commanders/directors and reflects integrated Air Force technology planning. I request Air Force Acquisition Executive approval of the plan.

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Commander
Phillips Laboratory

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Major General, USAF
Technology Executive Officer

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This thrust involves the development and transition of advanced optical systems for laser propagation and high resolution imaging applications. This includes technologies for adaptive optics, highly-accurate target acquisition and tracking, precision beam pointing for aimpoint control, and high quality optical components. Applications include Airborne Laser (ABL) Theater Missile Defense (TMD) and Ground Based Laser (GBL) Anti-satellite (ASAT).	
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This thrust involves the development and transition of multi-spectral sensing and image processing technologies for high resolution imaging applications. This thrust takes advantage of adaptive optics and target acquisition/tracking technologies developed under the Beam Control thrust to produce a compensated, stabilized image which can then be further improved with advanced imaging sensors and post-processing of the image. Advanced concepts which can reconstruct images from interferometric or speckle data are also being pursued along with developing an Intelligence Data Analysis System for Spacecraft (IDASS).	
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This thrust develops and transitions high power microwave (HPM) weapons technology into the AF operational inventory and protects US systems against potential radio frequency (RF) weapons threats. Efforts include technology development and demonstrations of advanced HPM technologies, and development and transition of RF hardening techniques to AF Product Centers and industry. This thrust also assesses the vulnerability of foreign space systems in support of advanced weapon technology development programs, and defines the hostile threat space environments in which US systems will operate. The challenge is to determine the effects of HPM on both foreign and US space systems and then to incorporate these findings into models and computer codes which predict space systems survivability.	
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INTRODUCTION

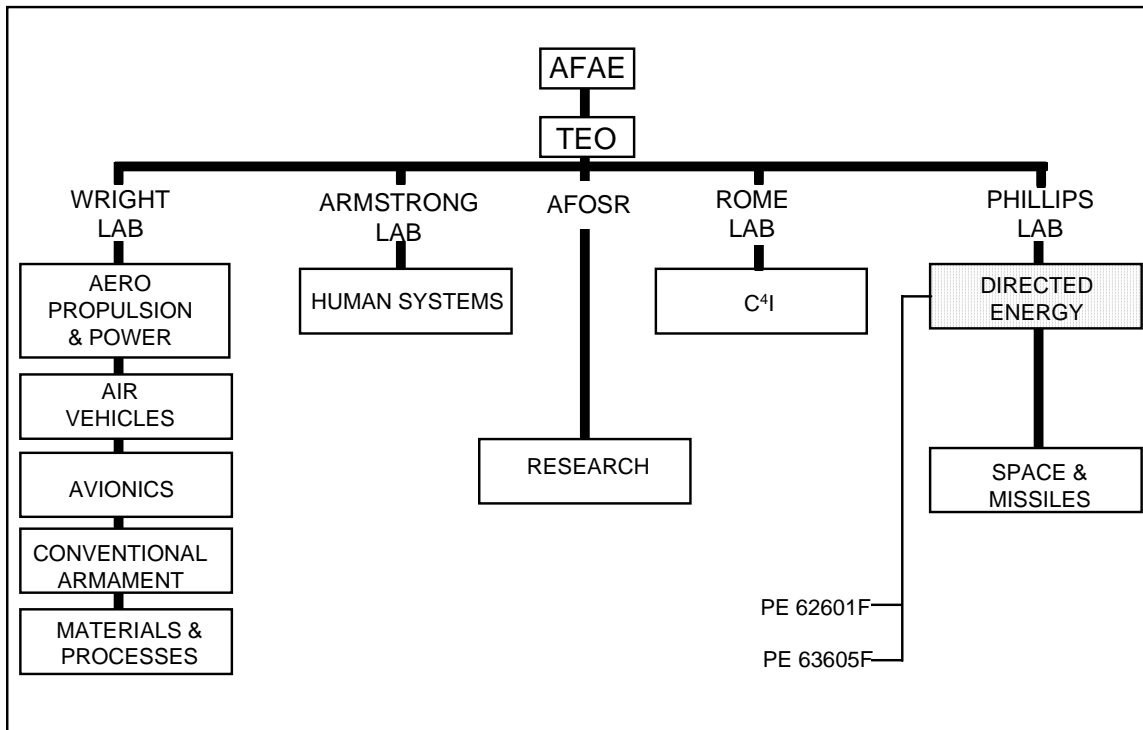


Figure 1. AF S&T Program Structure

BACKGROUND

The Directed Energy Technology Area is managed by the Commander of the Phillips Laboratory, as indicated in Figure 1. It is executed by the Advanced Weapons and Survivability and the Lasers and Imaging Directorates, with the majority of the technical activities performed at Kirtland AFB, New Mexico. This Technology Area encompasses the development, demonstration, and transition of directed energy and assessment of the survivability of USAF systems to similar foreign threats. For advanced weapon concepts, on-going and planned R&D will lead to high energy lasers, high power microwaves, high energy plasmas, and related capabilities such as high resolution optical imaging. Establishing the control and exploitation of space also requires the development of both hardening technology and the criteria for protecting USAF systems against directed energy weapons, nuclear weapons, and natural and enhanced space radiation.

Directed Energy is the one technology area where truly dramatic advances in warfighting capabilities will occur. The ultimate goal is new weapons development and transition,

enabling the Air Force to leap over the on-going evolutionary development process for conventional weapons, and thereby provide superior

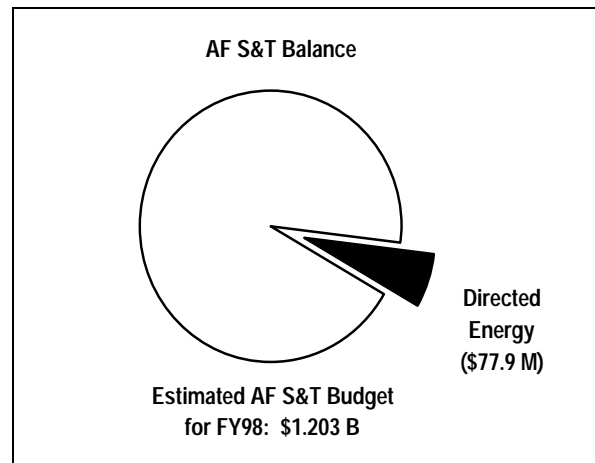


Figure 2. Directed Energy S&T Vs AF S&T

capabilities to support our national security.

Figure 2 shows the estimated Air Force S&T budget for FY98 with the exploded segment showing those funds that are programmed for Directed Energy.

The Directed Energy Technology Area is

transition of RF hardening techniques to AF Product Centers and industry.

Major milestones have been attained in demonstrating high power RF sources for a variety of wide- and narrow-band weapon applications -

- Aircraft self protection (ASP)
- Suppression of enemy air defenses (SEAD)
- Command and control warfare (C²W/IW)
- AF Space Control

A RF effects and hardening database is being built in concert with AF Information Warfare Center, and PL has developed an automated RF effects components and C²W subsystem testing capability to support these efforts. A full-scale mock-up of an F-16, from the cockpit forward, has also been constructed to support avionics systems HPM effects testing.

Thrust four also assesses the vulnerability of foreign space systems in support of advanced weapon technology development programs, and defines the hostile space threat environments in which US systems will operate. The challenge is to determine the effects of high power microwaves on both foreign and US space systems and then to incorporate these findings along with the laser effects from Thrust 1 into models and computer codes which predict space systems endurance and sustainability.

RELATIONSHIP TO OTHER TECHNOLOGY PROGRAMS

The Directed Energy technology area interacts with several other technology areas through a wide range of relationships with other agencies. These relationships range from informal coordination between technical personnel to formal program management direction. Specific relationships are established through interchanges at technical meetings, seminars and symposia. If appropriate, they are formalized through Memoranda of Agreement (MOAs) or Memoranda of Understanding (MOUs) which delineate the responsibilities for supporting directed energy technologies.

The Directed Energy technology area benefits from support for basic research provided by the AFOSR Research technology area. Individual tasks investigate a range of new technology concepts within four major thrusts, with potentially high payoff for transition to longer-term development and scaling efforts. Examples include the investigation of novel, short wavelength laser concepts, adaptive optics

phenomenology, basic physics issues for high performance optical coatings, aero-optics effects, advanced imaging concepts, high power RF sources, ultra high energy pulse power, and development of new parallel 3D codes for simulation of complex physics applications as well as performance of large-scale, three dimensional calculations.

There are many PL cooperative programs within the Air Force. In High Power RF Technology they include Wright Labs on IR missile countermeasures, Rome Labs on Information Warfare (IW), Armstrong Laboratory on Active Denial Technology, AFFTC & AEDC on RF test facilities for aircraft & satellites, and an Air Staff sponsored program on IW protection and hardening. The Materials Directorate, WL, is also pursuing development of high power optical component technology, which is directly relevant to the goals of the Beam Control thrust.

Among the Services, work in the directed energy area is coordinated through the Technology Sub-Panel for Directed Energy Weapons (TPDEW) of the Director of Defense for Research and Engineering's (DDR&E) Defense Technology Area Plan (DTAP). High Power RF Technology coordination has included transition of AF HPM sources to Army programs, leverage of RF effects tests on communications gear (MICOM) and missiles (MISIC & NRL) for AF programs, and cooperation on large aircraft RF effects tests and wide band source development at NSWC. The Federal Defense Laboratory Diversification Program is also the agent for transitioning RF effects developments to industry. There is an agreement among the services that the AF will support the development of adaptive optics technology for atmospheric compensation, with the resulting technology base available to the other services to support their applications.

There is also a significant degree of cooperative work with other government agencies and their laboratories. DOE laboratory representatives participate in TPDEW meetings to improve coordination and identify areas for cooperation. For example, cooperative or collaborative work exists with DOE laboratories on pulse power, compact HPM source development, RF effects tests, power beaming technology investigations, specialized security sensor development, RF coupling code development, and mid-IR semiconductor laser diode development. Power beaming and long range laser communications are being investigated with NASA, and RF threats to aircraft is being pursued with the FAA.

PL S&T investments are significantly enhanced by teammates in the industrial sector. There has been continuing emphasis on technologies oriented to airborne laser systems,

stimulated by the establishment of the ABL program. There also continues to be significant investment by industry in the area of high energy chemical lasers, advanced optical imaging, semiconductor laser diodes, HPM sources, and RF hardening. A close relationship with industry is also illustrated through a number of active Cooperative Research and Development Agreements (CRDAs) in areas such as laser development for materials processing and medical applications, optical coatings process development, HPM source development, and RF effects testing and hardening of commercial vehicles (GM), aircraft (Boeing), and computer components (Intel). Recently, an advanced metal detector system for detecting weapons carried by personnel was developed under a jointly funded effort between PL and private industry. This will revolutionize walk-through personnel security systems such as are located at airports.

PL manages the SMC Small Business Innovative Research (SBIR) program. In proposing topics for the SBIR program, one of the strong considerations has been the potential for commercialization of the potential product, as well as the innovation required for a solution. This concept maximizes the potential gain for both the small business and the government. There are five new SBIR Phase I efforts that have been awarded in April 1997. Three of the efforts address methods of extending the pulse duration of high power microwave (HPM) sources to improve output for both military and commercial applications. Another effort is developing ultra-wideband (UWB) waveguide bends to reduce or eliminate the losses in waveguide bends. This will allow UWB sources to be installed in aircraft and other configurations requiring complex waveguide routing. The other Phase I efforts address automatic identification of moving vehicles, optimization of wireless LANs using in-situ testing, and high power acoustics to provide security to facilities and control riots. Phase II SBIR efforts are developing a commercial version of the PL patented electronic mode stirred chamber to test electronic systems for EMC/EMI effects, development of a UWB antenna for installation on aircraft, and development of a network analyzer with integrated modulation capability to provide full characterization and testing of wireless communication systems. A successful Phase II effort has just been completed to develop a new class of instrumentation that allows simultaneous multiple distributed electromagnetic measurements that are time and frequency synchronized. This system is entering a Phase III commercialization phase with production and delivery of systems beginning in June 1997.

Interactions with international R&D

programs are productive in essentially all areas of research within the Directed Energy Technology Area. The interaction ranges from the exchange of data and information in areas of common interest, through the funding support of specific research initiatives in foreign countries, to the joint support of specific research and testing initiatives both at home and abroad. A total of 10 different international agreements are involved, with an estimated dollar value exceeding \$1 million.

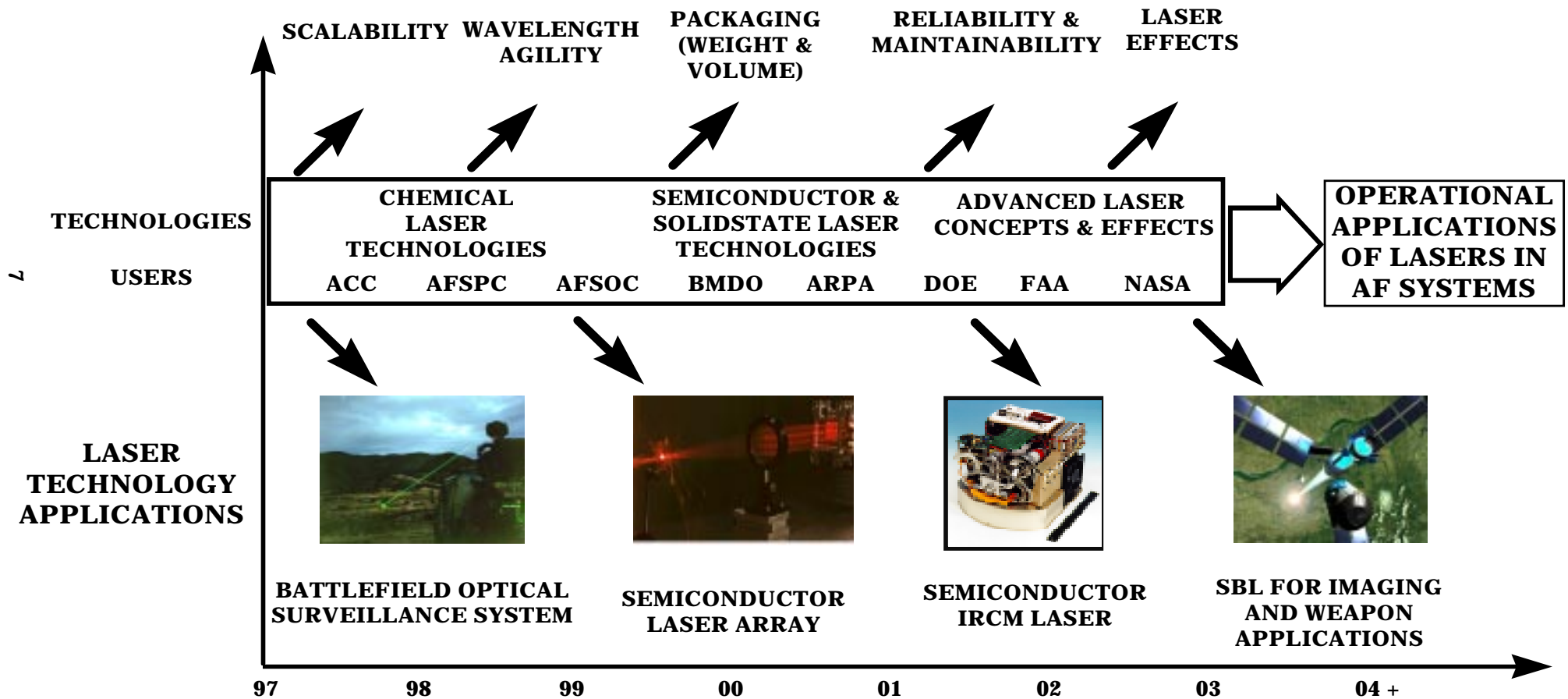
The Atmospheric Characterization effort of the Beam Control thrust closely collaborates with Geophysics programs in the Space and Missiles Technology Area to characterize the environment that affects Directed Energy systems. The program includes measurements and modeling of atmospheric optical turbulence, including meteorological dependencies.

CHANGES FROM LAST YEAR

The Directed Energy Thrust 5, Space Control Technologies, has been eliminated and reorganized under Thrust 4, High Power RF Technology, Thrust 1, Laser Technology, and Thrust 3, Imaging. Thrust 4's title has been changed from RF Weapons to High Power RF Technology. Reduced funding has resulted in limiting RF Space Control research to efforts aimed at general effects & RF technology development. Laser effects work from thrust five has been incorporated into subthrust 1C, Advanced Laser Concepts and Effects. The Intelligence Data Analysis System for Spacecraft (IDASS) has been incorporated into Thrust 3, Imaging. Additionally, two Focused Technology Areas (FTAs), Nonlinear Optics (A1D01) and Imaging Applications (A3A06), have been eliminated with the work allocated to other FTAs. All space debris work has been transferred to the Space and Missiles Technology area. The balance of Thrust 5, Threat Warning and Attack Reporting, and Satellite Assessment efforts has been moved to Thrust 4, EM Effects & Hardening.



DIRECTED ENERGY LASER TECHNOLOGY



chemical efficiency and size and weight reduction. Current work with the advanced diagnostics will lead to avenues for further improvements in chemical efficiency. Also being examined are more fieldable forms of Basic Hydrogen Peroxide. Additionally, the development of a COIL based illuminator is required for risk reduction for the ABL and GBL systems. Current work will include examining the development of high average power frequency conversion, the incorporation of an unstable resonator on the RADICL device and gain switching of RADICL. These efforts will continue through FY97 and FY98.

Single semiconductor laser diode technology development continued in FY97 to obtain devices with up to 10 watts continuous output and good beam quality. These devices will be transitioned to meet near-term user needs.

Efforts to understand the mechanisms generating TeraHz radiation in InSb by sub-100 femtosec laser pulses have been completed. Also, the first observation of the carrier dynamics in HgCdTe with various compositions, has been accomplished. Building on these successes, extension of these studies into the 2-5 micron region will continue. Fourier Transform Spectroscopy experiments involving the TeraHz radiation are ongoing. Propagation of these ultra-short laser pulses will continue. Radiative effects experiments and investigations are scheduled to continue through FY00. Various nonlinear methods are being investigated with the goal of producing, by FY02, a high power source (1000 W) operating from the near-ultraviolet through the visible to the near-infrared wavelength region.

Vulnerability studies to assess the effectiveness of the ABL in adjunct missions are continuing. The adjunct missions include protection of high valued assets, Suppression of Enemy Air Defense (SEAD), and cruise missile defense. Additionally, the evaluation of laser induced contamination of spacecraft components is progressing through FY97/98 in support of GBL and SBL programs. The results will yield criteria for causing temporary or permanent degradation of spacecraft.

improve ABL performance. Milestone I for ABL was successfully passed in November 1996, concluding questions on the maturity of critical criteria: laser power and scalability; atmospheric turbulence characterization, active compensation performance, and active tracking of boosting missiles. These same criteria remained prominent concerns for the program's first Authority to Proceed (ATP-1) scheduled for summer 1998. The beam control thrust closed two of four ATP criteria (active compensation and active tracking) successfully in FY96 and early FY97, and is contributing to closure on the atmospheric data base.

Prior atmospheric measurements from ABLE-X (FY93) and ABLE-ACE (FY95) verified that statistics for at-altitude atmospheric turbulence essentially obeyed theoretical (Kolmogorov) projections. These important experiments indicated the PL/GP CLEAR I turbulence model for ABL scenarios, and the basis for ABL development were sound. Milestone I recognized the validity of these conclusions. Collection of atmospheric data will proceed through FY97 and 98, filling in a world-wide data base to validate the application of ABL models to global combat capability. Characterization of the turbulence in two operational theaters (Korea and the Mid-East) is proceeding for each quarter of FY97 and FY98. ABL SPO personnel will use technical assistance from the Phillips Laboratory Geophysics and Lasers and Imaging Directorates for aircraft and balloon-borne measurements to build a robust database of turbulence measurements to characterize the obstacles to full ABL capability. The first of these joint measurements occurred in late April 1997. In addition, S&T assets will be conducting joint balloon-borne, aircraft, and radar tests at White Sands Missile Range in late FY97 to verify the statistical correlation of these measurements, and anchor turbulence models in three dimensions.

Active tracking of a theater ballistic missile (including plume-tracking, illumination, and hand-over) was successfully demonstrated in a joint AF/Army test at WSMR in late FY96 and early FY97. The active track test, against a Black Brandt missile, was demonstrated four times, using the Navy's Sea-Lite Beam Director (SLBD), modified by Phillips Lab personnel. This demonstration, and the ensuing report, closed early one criterion (active track of a boosting missile) for ATP-1. Advanced tracking concepts will be necessary to extend this capability to further ABL lethality. Early construction and experimentation have begun to establish an

Advanced Tracking Laboratory at Kirtland AFB to test and refine tracking algorithms and hardware for inclusion on later ABL platforms. The advanced tracking laboratory will reach initial operational capability in FY98.

Simultaneous active tracking and active compensation are the fourth of four criterion for ATP-1 to be passed. Tests at MIT Lincoln Laboratory's Firepond test range have been exploring this concept and conclude in late May, 1997. Once these tests have concluded, and data to support ATP-1 gathered, equipment will be transferred to support an Advanced Compensation Laboratory at MIT/LL facilities on Hanscom AFB.

Both the Advanced Compensation Lab and the Advanced Tracking Lab will conceptualize and explore risk reduction and performance enhancement ideas to further ABL performance. The remainder of the FY97 effort and most of FY98 will involve standing these laboratories up and completing construction on the ABL-scaled testbed to be located at North Oscura Peak on WSMR. Construction on this 1/6 ABL-scaled site will begin in late FY97 and proceed to active tracking of missiles-of-opportunity in late FY98. This testbed will be used to verify innovative beam control systems to gain significant improvements in ABL performance--two to five times better engagement time and range have been predicted for some proposed improvements.

During late FY96 and early FY97, a 37 inch diameter optic was coated at the PL Optical Coating and Component Evaluation Laboratory (OCEL) for LANL. The process for deposition of ZrO_2 was successfully scaled for use in the large coating chamber to meet the requirements of this unique coating design. A large, 22 inch window was also coated in the OCEL in support of an SOR experiment. In addition to the successful completion of these large area coatings, several coatings were also deposited for other PL projects.

The use of Ion-Assisted Deposition (IAD) to further reduce the scatter and improve the durability of coatings was also initiated during the past year at the OCEL. Studies of single layer films are on-going, but preliminary results indicate a substantial reduction in scatter for some oxide coating materials.

MILESTONES

This thrust results in full-scale demonstrations of GBL beam control technologies

through FY00. Installation of a 941-channel adaptive optics system for the 3.5 meter telescope and the first demonstration of star-loop atmospheric compensation performance will be completed in FY97. Key FY97 experiments will include compensated imaging of both astronomical objects and satellites, followed by compensated low-power laser propagation. Active tracking of dim satellites without retro-reflectors will be done in late FY97. Work in parallel on tracker upgrades, aim point designation and control algorithms, and improved satellite acquisition methods will be incorporated, leading to full-scale, low-power field tests of acquisition, tracking, and pointing technology appropriate for GBL applications in FY98-99. The performance metrics are the residual tracking error and the beam pointing accuracy which can be achieved against realistic satellite targets.

The final demonstrations for GBL beam control will emphasize integrated performance of the overall beam control system, including all the functions necessary for a satellite engagement (acquisition, tracking, pointing, and atmospheric compensation). The goal is to demonstrate integrated performance which meets the requirements for a full-scale GBL system, thereby establishing the maturity of beam control technology for these applications.

Dynamic tests of tracking concepts and algorithms were completed at White Sands Missile Range. This set of experiments represented the first ever active track demonstration against full-scale theater ballistic missiles. The technology demonstration, against four Black Brandt missiles closed one of the final Milestone I criterion. Simultaneously the experiment closed, 1 ½ years early, a critical Authority to Proceed criterion. This proof-of-concept was a major risk mitigation effort for the ABL.

Active compensation efforts by Phillips Laboratory and MIT Lincoln Laboratory personnel have thoroughly established the maturity of traditional adaptive optic methods to compensate for atmospheric distortion to the degree necessary for ABL lethality. This technology demonstration also closed early (by one year) an ABL risk mitigation criterion. In long range technology demonstration programming, the preliminary and critical design reviews for the North Oscura Peak testbed proceeded on schedule in February and May respectively, of FY97. This ABL Advanced Concepts Testbed (ABL ACT) will be used as a 1/6 scale model for ABL improvements. Proposed testing, both in-house and by ABL-team contractors, will proceed in late FY98 in time to

field improved compensation techniques on the PDRR version of the ABL.

The demonstration of a bonding technique for fused silica cooled optics, and identification of a non-toxic coolant is to be completed during FY97. Cooled transmissive optics may be required for beamsplitters or other high energy density window applications.

THRUST 3: IMAGING

USER NEEDS

This thrust supports the following mission areas and associated technology needs or deficiencies, as provided in the current Mission Area Plans (MAPs), through the development of advanced imaging and remote sensing techniques. Involved are passive and active (laser illumination of targets) methods to improve the resolution, extend the time availability, and reduce turnaround time for space surveillance data. Conventional and nonconventional methods are being developed to increase the information obtainable by the optical observation system and to increase the range from low earth orbit (LEO) to geosynchronous (GEO) altitudes. Additional efforts address the improvement of airborne and space-based imaging systems.

Air Force Space Command

1. Space Surveillance: Inadequate continuous near earth coverage; limited space intelligence support; limited coverage, multi-phenomenology; SOI, MPA, imagery, status assessments.
2. Command and Control: Surveillance coverage; deep space surveillance.

Air Force Special Operations Command

1. Joint Air-SOF Battlefield Interface: No real/near real-time information from national systems.
2. Force Application: No real-time information for target study; no en-route real time information; enhance target identification capability.
3. Psychological Operation: No real/near real-time information from national systems.

Counterproliferation

1. Includes Air Combat Command, Defense Intelligence Agency, and the CINCs.
2. Long Range (>100km) detection & identification of development, production, and test of weapons of mass destruction.
3. Detection and identification of illicit drug production.
4. Long range detection and characterization of battlefield use of weapons of mass destruction.
5. Battle Damage Assessment: Assess damage & need for follow-up strikes against underground storage facilities for weapons of

mass destruction.

GOALS

The goals of the Imaging Thrust are to develop and transition advanced optical systems and multi-spectral sensing technologies for tactical and/or strategic applications to meet user needs in the areas of quality optical imagery and remote sensing. Specific goals include:

1. Develop active imaging techniques to obtain images of LEO objects, and extend these technologies to reach deep space or GEO objects.
2. Develop technologies for lightweight space optics, scene based wavefront sensing, electro-optical (EO) adaptive optics and on-board image processing.
3. Develop passive imaging techniques to obtain images of LEO objects, and extend these technologies to reach deep space or GEO.
4. Develop advanced EO devices to support other AF missions, including long range laser target designators, optical reconnaissance and surveillance of chemical and biological weapons in production or in use on the battlefield.
5. Develop nonlinear optical systems to automatically correct for dynamic optical errors introduced by the atmosphere, and to correct for static errors to very large diameter, lightweight, deployable primary mirrors on imaging satellites.
6. Evaluate multi/hyper-spectral, thermal, radiometric sensor technologies for space applications; develop parallel processing technologies for real-time image analysis; develop high-resolution, ground-based optical imaging technology and signature data collection capabilities for detailed threat assessments; develop advanced intelligence data analysis technologies for spacecraft sensor data fusion and identify advanced methods to exploit all-source intelligence data; and develop simulation and display technologies for realistic training and exercise support for operators.

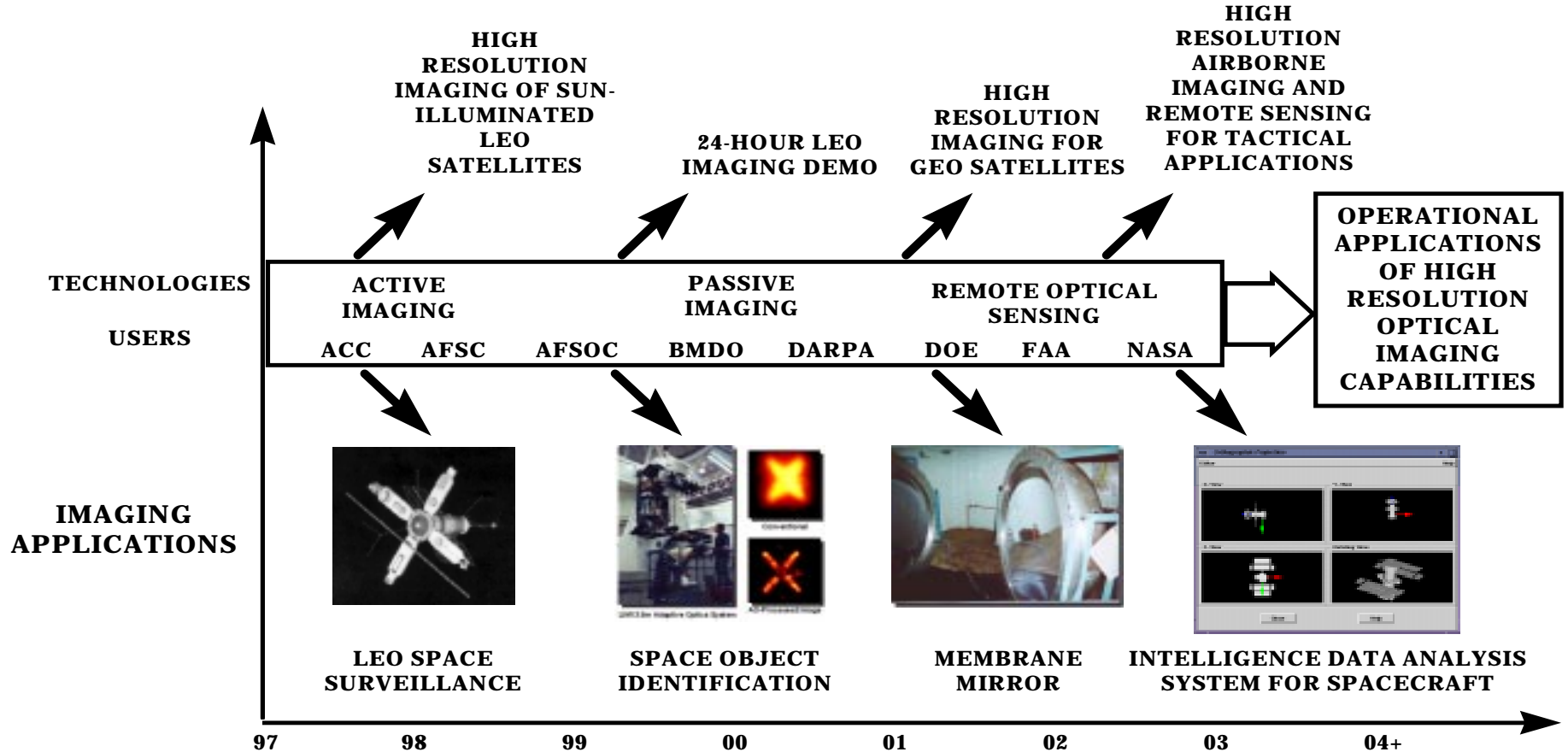
MAJOR ACCOMPLISHMENTS

Several major accomplishments during the past year have contributed significantly toward the achievement of technical goals and addressing stated user needs and deficiencies. These



DIRECTED ENERGY IMAGING TECHNOLOGY

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accomplishments range from the successful completion of laboratory proof-of-principle experiments to the demonstration of techniques in realistic field experiments.

The High performance CO₂ LADAR Surveillance Sensor (HI-CLASS) laser operated in the LIDAR mode, April 97, on the top of Mt. Haleakala, Maui, HI. Directing the laser at a ground site 18 km away, liquid trichloroethylene was detected – the first time a liquid has been used in the test cell. HI-CLASS is currently operating at 30J, 30Hz and primarily supports Space Object Identification (SOI) efforts for AFSPC, but the high altitude of Mt Haleakala makes it possible to simulate a LIDAR on an aircraft for experiments supporting counter-proliferation and drug inter-diction.

The Argus team successfully supported the Defense Special Weapons Agency's Dipole Tiger 1 tests at White Sands Missile Range (WSMR). The tests simulated bombing of a chemical weapons bunker to study propagation of chemicals. The Argus wide and narrow field cameras recorded the explosion and the Nonproliferation Airborne LIDAR Experiment (N-ABLE) detected and tracked gaseous effluent from the debris. This test provided excellent results and evaluated methods of locating and tracking chemical clouds from an uncooperative target.

The Space Based Imaging Program continues research of large, high resolution, lightweight imaging systems for geosynchronous orbits. A meter-class laboratory breadboard for use in the characterization of nonlinear optical (NLO) and electro-optical (EO) wavefront correction techniques was successfully constructed. The breadboard includes a lightweight primary mirror that can be deformed in a controllable manner to meet expected figure conditions for a sensor satellite. The NLO correction technique will be demonstrated in a lab setting by 1Q FY98, followed by an EO demonstration by 3Q FY98.

Also within the Space Based Imaging Program, a new membrane mirror for space-based imaging applications has been designed. This design is specifically made to address various optical imaging issues associated with membrane mirrors. The present design will be improved in order to build a meter-class membrane mirror. This meter-class membrane mirror can then be tested in the above mentioned laboratory breadboard.

Construction and testing of an airborne brass-board for the MightySat II.1 hyperspectral payload was completed within the spectroradiometry program. The spaceborne payload has been designed and we are now building the sensor and developing analysis capability in anticipation of an FY99 launch. Polarimetric sensors and analysis techniques are being developed for a

MightySat follow on system to be launched in FY01 or FY02.

The active remote sensing program has field tested the N-ABLE system. A longer range version, called Laser Airborne Remote Sensing (LARS) is being integrated in FY97 and will be tested in FY99.

The Intelligence Data Analysis System for Spacecraft (IDASS) - Phase II of five year, four phased IDASS program, was installed and demonstrated within the USSPACECOM's Combined Intelligence Center (CIC). This years' development demonstrated more advanced exploitation capabilities and linkage to additional space surveillance collection assets.

CHANGES FROM LAST YEAR

Limited funds for active imaging programs has resulted in stretching the programs into FY98. U.S. Pacific Command and AFSPC have both increased the level of processing on the supercomputer. AFSPC has continued progress on transitioning the Maui Space Surveillance Site to total operational control and has officially accepted the site as an operational entity.

This year the NLO research was combined with the Space Based Imaging Program. The continued research into membrane and active optics has made the integration of smart sensors for beam control and wavefront control necessary. The program's goal is the development of technologies for a high-resolution, lightweight optical sensing satellite. Tasks include: characterization of deployable, inflatable primary mirrors, NLO and EO correction techniques for use on ultra-lightweight, low quality telescope optics, and smart optical sensors for figure control, active control, and image processing.

The Imaging Applications FTA (A3A06) was eliminated with the work added to the Advanced Imaging Concepts FTA (A3A05).

The IDASS subtask from Thrust 5 has been moved into this thrust.

MILESTONES

A passive technique, compensated daylight imaging, builds upon the results of field tests at Starfire Optical Range and on improved image processing algorithms, and was used to demonstrate imaging of ultra-dim objects in FY97 at MSSS. By mid-late FY97, the upgraded Observatory Control System was completed and transitioned to AFSPC, allowing for improved operation at the site. Continuing developments in sensor and adaptive optics systems also provided the technology for an improved operational capability at the Advanced Electro-Optical Sensor (AEOS). The 3.67 meter primary mirror for the

AEOS telescope was successfully coated at Kitt Peak Observatory in Feb. 97, with installation at the Maui facility in April 97. The system will be completely operational in FY99 after delivery and installation of the required sensors.

Another effort, funded through a Congressionally-directed initiative, is the development of an Active Imaging Testbed. With continued funding support, the completion of illuminator laser development, the integration of optical receiver hardware, and the demonstration of a limited active imaging capability is planned for the end of FY97. Follow-on experiments will refine LEO imaging techniques. Subsequent active imaging work will extend the capability to GEO targets, with anticipated start of tests during FY00.

A full capability Hi-CLASS laser radar system is expected to be on line at MSSS during FY97. This system will be used to demonstrate Doppler imaging of LEO satellites and evaluate the potential for space debris detection and sampling.

Airborne hyperspectral measurements and LIDAR demonstrations in FY97 support the development and demonstration of an airborne testbed for active remote sensing for reconnaissance and surveillance of chemical weapons in production or use on the battlefield.

Milestones within the Space Based Imaging Program include an FY98 laboratory demonstration of EO correction of figure errors in a meter-class, lightweight primary telescope mirror; an FY99 start for design and construction on a lightweight imaging satellite optical brassboard mock-up to be tested and space qualified in a NASA provided space environment simulation facility; and an FY02 start of space experiments.

Intelligence Data Analysis System: The IDASS Phase IV is scheduled to be delivered to CIC in the 3Q98.

THRUST 4: HIGH POWER RF TECHNOLOGY

USER NEEDS

This thrust supports the Air Combat Command (ACC), Air Mobility Command (AMC), Air Force Special Operations Command (AFSOC), and Air Force Space Command (AFSPC) mission areas and associated technology needs or deficiencies as provided in the current Mission Area Plans (MAPs). The needs listed below have been examined by the Product Centers' Technical Planning Integrated Product Teams (TPIPT)s, and documented in their Technology Investment Recommendation Reports (TIRR)s.

1. Counter Surface-to-Air & Air-to-Air Missiles
2. Large Aircraft IR Countermeasures
3. Suppression of Enemy Air Defenses
4. Air Interdiction of C^I Defenses
5. Degrade Enemy Air Control
6. Degrade Enemy Military Base Operation
7. Reduce Enemy Sortie Generation
8. Hardened Target Weapons
9. Agent Defeat Warheads
10. Less-Than-Lethal Weapons
11. RF Disruption of Electronic Systems

RF Effects and Hardening is a pervasive need driven by requirements at several different levels. The Operational Commands and Air Logistic Centers (ALCs) have articulated their user level needs for RF Effects Systems Survivability. The Phillips Lab is the prime executor of high power RF effects and Hardening programs, and, as required, supports customers in more general EMI/EMC efforts.

AFSPC Space Control requirements are taken from the Space Surveillance, Counterspace and Missile Defense MAPs. SMC requirements derive directly from the AFSPC Space Control MAPs. Needs supporting these areas are listed below:

Counterspace Protection

1. Attack and Fault Detection Sensors
2. Satellite Threat Warning/Attack Reporting
3. Natural and Threat Environment Protection of EO and RF Systems
4. Active Protection Technologies

Missile Defense

1. Decision Support Systems
2. Enhanced Data Fusion Technology
3. Survivability Techniques

GOALS

The overall goals of the High Power RF Technology thrust are to develop and transition high power RF technology into the operational inventory, and to protect US systems against the expanding threat represented by similar foreign systems. Also, the primary goal in surveillance and protection is to develop advanced technologies to improve operational force capabilities for maximizing situation awareness, accelerating the decision and tasking process, and protecting US and Allied space systems.

The *Weapons Applications* portion of this thrust is organized under four Mission Application programs which perform research in response to user needs. The goals under these programs seek to provide revolutionary rather than incremental advances in the force capabilities. The four programs and their goals are:

1. HPM Aircraft Self Protection (ASP)
 - Develop technology for wideband HPM Countermeasure (CM) to protect aircraft against Infrared (IR) and other precision guided missiles in a non-system specific manner.
2. HPM Suppress Enemy Air Defenses (SEAD)
 - Suppress enemy air defenses and burn out electric components within an enemy's Integrated Air Defense System (IADS).
3. HPM Command Control Warfare (CCW)
 - Temporarily or permanently render C³ installations inoperative.
4. RF Active Denial Technology (ADT)
 - Demonstrate and transition RF Active Denial Technology

The *Source Components* goal is to provide Directed Energy Weapons Programs with pulsed power, RF sources and antennas, and sources for effects measurements.

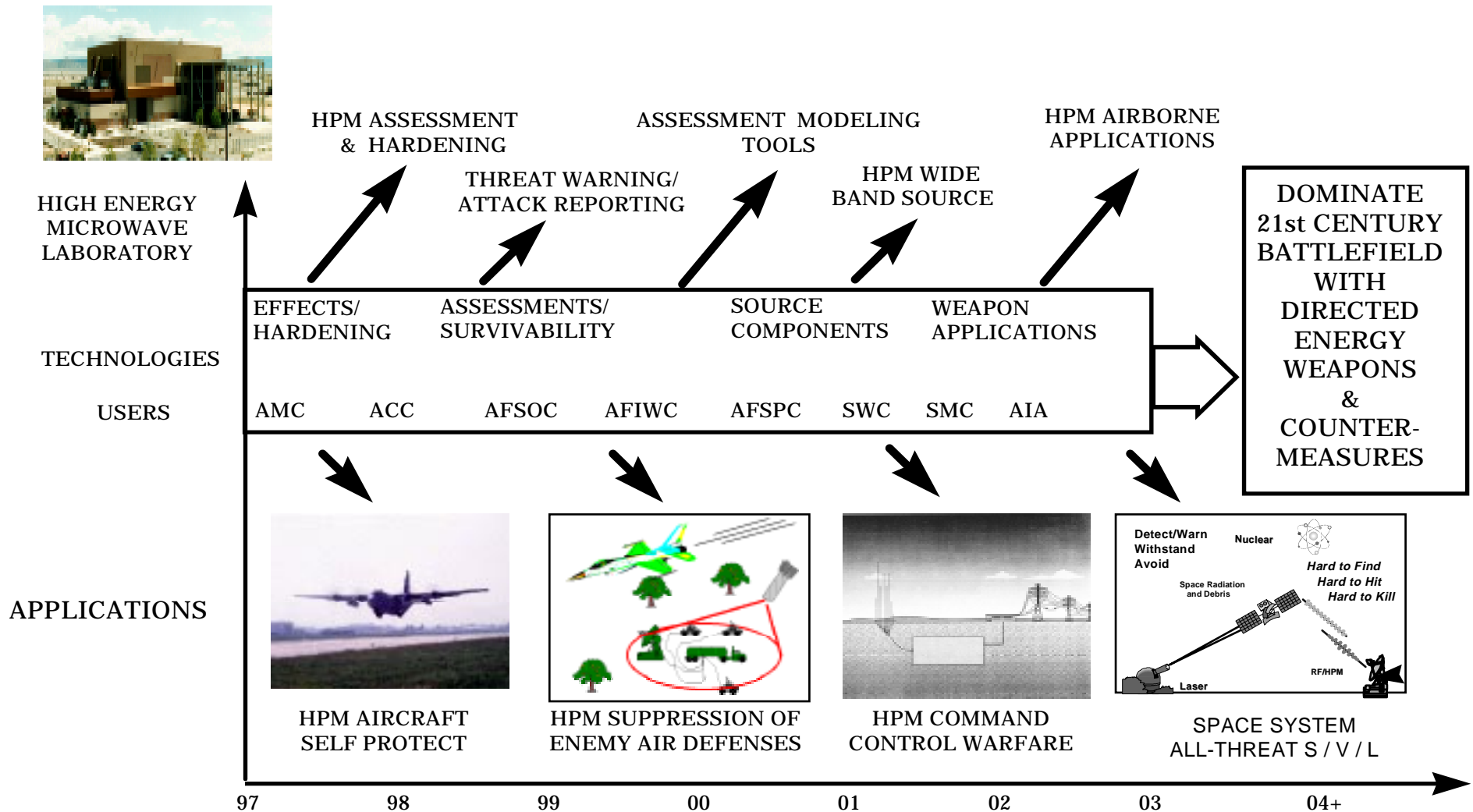
The *RF Effects and Hardening* goal is to develop the capability to determine microwave frequency susceptibility and hardening requirements for specified systems and subsystems.

The *Assessments and Survivability* specific technology goals are:



DIRECTED ENERGY HIGH POWER RF TECHNOLOGY

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1. Counterspace Protection: Develop threat warning and attack reporting architecture and enabling technologies. Develop techniques to make materials capable of withstanding the effects of electromagnetic, and other advanced weapon attacks. Develop technology solutions that help prevent enemy use of US space systems. Develop advanced all-threat satellite response modeling and assessment capability. And identify, evaluate, demonstrate and transition high-data rate, survivable communications technologies, along with near real-time DEW deconfliction technologies..
2. Missile Defense: Quantitatively assess the effectiveness of RF weapons against missile borne weapons; develop technologies for sensor data fusion and image simulation; develop simulation and display technologies for training and exercise support; enhance and apply all-threat modeling; develop Battle Damage Assessment (BDA) technologies for assessments and rapid decision support.

The result is a fully integrated approach to RF Systems Effects, Vulnerability, and Lethality, covering natural, inadvertent man-made, and potential hostile RF weapons threats.

CHANGES FROM LAST YEAR

RF Weapons was reorganized during FY 97 to include technology areas from Thrust 5 which was eliminated. Space Debris was transferred entirely to the Space & Missiles Tap. A new subthrust, Assessments and Survivability, was created to incorporate the remaining areas. The RF Space Control area was phased out due to funding cancellation. The Laser Effects effort was transferred to Thrust 1, Laser Technology and IDASS was transferred to Thrust 3, Imaging.

MAJOR ACCOMPLISHMENTS

HPM Sources: Some notable achievements during the previous year: World Records Set

1. The Relativistic Klystron Oscillator (RKO) design set a record for total energy radiated, power radiated and efficiency: 1.5 Gigawatts (GW) and total energy extracted of 170 Joules. This results in a significant cost and weight savings for the device.
2. The Magnetically Insulated Line Oscillator (MILO) also set a world record with a power extracted of 2.0 GW and total energy extracted of 300 Joules.
3. Also, some of the first future weapons' energy sources were tested. Known as Magnetocumulative Generators (MCG)s, over 25 successful explosive shots were conducted at the High Energy Research & Test Facility (HERTF). Currents approaching 750 Kiloamps (kA) were

generated from a 22 kA initial current.

HPM Antenna development:

1. Coaxial Beam Rotating Antenna (COBRA):
 - A brassboard design of the COBRA was demonstrated which will be used with several HPM sources. The COBRA is one of a number of HPM antenna designs which combine mode conversion and beamwidth control into one compact device.
2. Ultra Wideband (UWB) High Voltage Horn Antenna:
 - Researchers successfully demonstrated a new design in UWB antennas. The new horn design incorporates several novel concepts including a Point Geometry Mode Converter capable of sustaining up to 13 megavolts per centimeter and a Brewster Angle window to transition the high voltage pulse from oil to air.
3. Lensed Horn UWB Antenna:
 - The theory and concept for two UWB antennas designed to radiate and receive extremely short transient waveforms at high levels of voltage was developed. Both antennas were demonstrated to have flat frequency spectra ranging from 500 MHz to 30 GHz and to be capable of radiating with a risetime of 23 picoseconds. These antenna designs have greatly improved the performance of underground radar and ground penetrating weapons.

New Parallel Codes Developed:

1. A new parallel , 3D Particle-In-Cell code called "Icepic" was developed and now allows simulation of devices such as HPM generators yielding more efficient valuable design information.
2. A new Phased Array Antenna Analysis (PARANA) software was developed. PARANA provides a new capability to accurately predict the electromagnetic (EM) properties of general periodic structures. This gives more accurate antenna designs, and prediction of EM penetration through conducting screens, reinforced concrete, and fiber composites.
3. A parallel, 3D Magneto Hydrodynamic Code, MACH3, was rewritten for parallel-processor super computers. For the first time, the real-world case of 3D simulation of magnetofluid is obtainable.

Assessments and Survivability

1. First Time Multiple Space Threat Testing of Detector Array - The survivability group performed experiments at its High Frequency Microwave Facility measuring for the first time a detector's response to "multiple

threats". These experiments will ultimately lead to satellite-borne sensors which will perform effectively in hostile environments.

MILESTONES

The technology activities of the High Power RF Technology Thrust are converging on several mission applications culminating in a series of CEs and ATDs during the next five years. The most critical program milestones are associated with generating the RF effects requirements database, demonstrating candidate HPM sources, and integrating the down-selected systems into practical packages for the mission applications. Although the Metrics associated with these milestones are classified, the calendar of major events are listed below:

1. Suppression of Enemy Air Defenses (SEAD)
 - Complete Critical Experiments 4Q98
 - Complete ACTD 4Q00
2. Aircraft Self-protect
 - Sub-scale source for static field test- 4Q97
 - Full scale source for live fire field test 4Q98
3. Active Denial Technology
 - Ground phased demo 4Q99
4. Command & Control Warfare:
 - Advanced Concepts Technology Demo in FY98 with strong user/OSD support.
5. RF Effects & Hardening:
 - Phase 1 & 2 Orlon Fiber Effects Experiment - 4Q97
6. Threat Warning/Attack Reporting:
 - Commercial microbolometer evaluation 4Q97
7. Assessments:
 - Complete multi-threat CCD/telescope demo - 4Q97
 - Evaluate composite material impact on S/C EM properties - 4Q97
8. Protection Technologies:
 - Integrate protection technology state of the art data in sensor model - 4Q97

	I		N
IADS	Integrated Air Defense System	N-ABLE	Nonproliferation Airborne Lidar Experiment
IDASS	Intelligence Data Analysis System for Spacecraft	NASA	National Aeronautics & Space Administration
IR	Infrared	NATO	North Atlantic Treaty Organization
IRCM	Infrared Countermeasures	Nd:YAG	Neodymium Yttrium Aluminum Garnet
	J	NLO	Nonlinear Optics
J	Joule		
JDL	Joint Directors of Laboratories		
	K		O
kA	Kiloamps	OSD	Office of the Secretary of Defense
KEW	Kinetic Energy Weapons		
km	kilometers		
kW	kiloWatts		P
kHz	kiloHertz		
	L	PARANA	Phased Array Antenna Analysis
LADAR	Laser Detection and Ranging	PL	Phillips Laboratory
LANL	Los Alamos National Laboratory	PMD	Program Management Directive
LARS	Laser Airborne Remote Sensing		R
LASSOS	Lasers and Space Optical Systems	R&D	Research & Development
LEO	Low Earth Orbit	RADICL	Research Assessment Device Improvement Chemical Laser
LIDAR	Light Detection and Ranging	RKO	Relativistic Klystron Oscillator
LIME	Laser Induced Microwave Emission	RF	Radio Frequency
			S
LLNL	Lawrence Livermore National Laboratory	S&T	Science & Technology
LPD	Low Probability of Detection	SBIR	Small Business Innovative Research
LPI	Low Probability of Intercept	SBL	Space Based Laser
	M	SEAD	Suppression of Enemy Air Defenses
m	meter	SHIVA STAR	Free world's most powerful fast capacitor bank
MajCom	Major Command	SLBD	Sea Lite Beam Director
MAP	Mission Area Plan	SMC	Space & Missile Systems Center
MCG	Magnetocumulative Generator	SNL	Sandia National Laboratory
MILO	Magnetically Insulated Line Oscillator	SOI	Space Object Identification
MOA	Memoranda of Agreement	SOR	Starfire Optical Range
MOU	Memoranda of Understanding	SPO	System Program Office
MPA	Mission Payload Assessment	S/V/L	Survivability/Vulnerability/Lethality
MSSS	Maui Space Surveillance Site	SWC	Space Warfare Center
mW	milliWatt		
MW	MegaWatt		
			T
		TAME	Tilt Anisoplanatism

TAP	Measurement Experiment
TEO	Technology Area Plan
TMD	Technology Executive Officer
TPDEW	Theater Missile Defense
	Technology Panel for Directed
	Energy Weapons
TPIPT	Technology Planning Integrated
	Product Team
TW/AR	Threat Warning/Attack
	Reporting
TIRR	Technology Investment
	Recommendation Reports

U

USSPC	US Space Command
UWB	Ultra Wideband

W

WL	Wright Laboratory
WSMR	White Sands Missile Range

MAP	6,14,18		
MCG	20		
MILO	20		
MOA	4		
MOU	4		
MPA (Mission Payload Assessment):	6,10,14		
MSSS	16		

W

WL (Wright Laboratory)	4,8
WSMR	3,12,16

N

NASA	4,17
N-ABLE	16
Nd:YAG	2,8,10
NLO (Nonlinear Optics):	i,,5,8

O

OSD	21
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P

PARANA	20
PL	i,ii,4,5

R

R&D	i,1,5,8
RADICL	2,8
RF	i,ii,iii,2,3,4,5,18,20,21
RKO	20

S

S&T	ii,1,4,12,26
SBIR	5
SBL	iii,6
SEAD	4,9,18,21
SLBD	12
SMC	5,18
SOI (Space Object Identification):	6,10,14,16
Space Control:	4,5,6,8,10,18,20
SOR (Starfire Optical Range):ii,	2, 3, 8, 10
SPO	12

T

TAME	2,10
TAP	20
TEO	26
TIRR	18
TMD	i,iii,2,3,6,8,10
TPDEW (Technology Panel for Directed Energy Weapons):	4
TPIPT (Technology Planning Integrated Product Team):	18