FY 97
GEOPHYSICS
TECHNOLOGY AREA PLAN

HEADQUARTERS AIR FORCE MATERIEL COMMAND
DIRECTORATE OF SCIENCE & TECHNOLOGY
WRIGHT-PATTERSON AFB OH

Note: This Technology Area Plan (TAP) is a planning document for the FY97-03 S&T program and is based on the President's FY97 Budget Request. It does not reflect the impact of the FY97 Congressional appropriations and FY97-03 budget actions. You should consult PL/XPG, DSN 478-3606, for specific impacts that the FY97 appropriation may have had with regard to the contents of this particular TAP. This document is current as of 1 May 1996.

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The FY97 Geophysics Technology Area Plan describes Phillips Laboratory's exploratory and advanced technology development strategy to support AF environmental and Army air and combat operations. Systems that sense environmental conditions from space will be increasingly important in providing this support. Objective is to improve the specification and forecasting , for longer periods and more precisely, of performance limiting battlespace conditions wherever our forces operate.

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Weather, Forecast, Electronic Warfare, Atmospheric, Electronic Systems Center, Counterproliferation, Celestial, FISTA, Geophysics, GPS, Navigation, Space Surveillance, Space Weather, LIDAR, Meteorological Satellite Program, AF Weather Service

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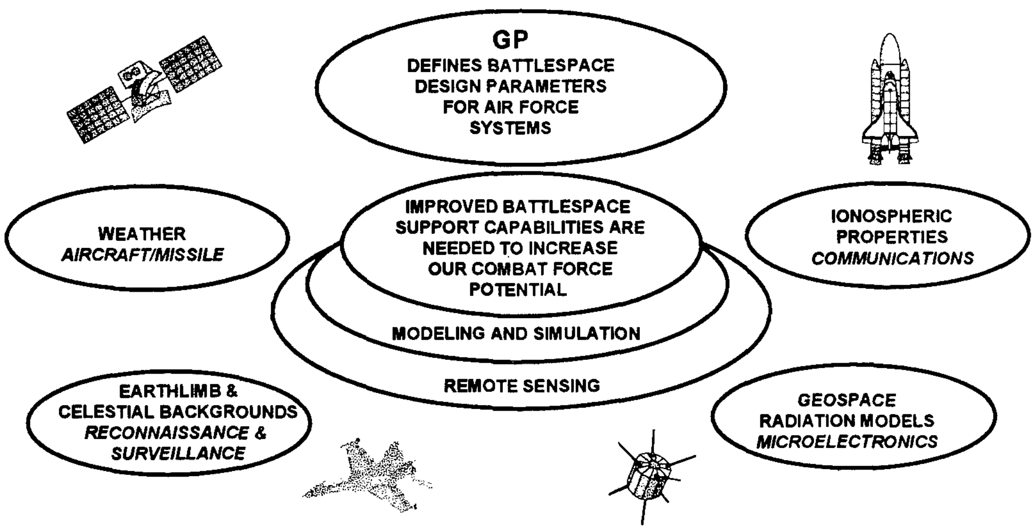
GEOPHYSICS



VISIONS AND OPPORTUNITIES

The Phillips Laboratory (PL) primary mission is to create technologies for the warfighter to control and exploit space. To accomplish this, a team of dedicated professionals is building the world's most respected military space laboratory

PL develops and maintains the technology base to support Air Force (AF) requirements for space and missile systems. PL also develops and maintains the technology base for directed energy and geophysics beyond their space applications to support other AF and Department of Defense (DoD) requirements.

The environment in air and space:

- limits the operation,
- raises the cost,
- degrades the performance of systems, and
- can provide an opportunity to exploit superior AF technology over our adversaries.

The Geophysics Directorate (GP) is seen as the DoD center of excellence for providing critical battlespace environment technology. The GP mission is to

- understand and
- mitigate or
- exploit for military advantage

the interactions between the battlespace environment and present and future DoD systems.

Geophysics science and technology (S&T) programs support AF and Army air and combat operations. Systems that sense environmental conditions from space will be increasingly important in providing this support. A GP vision is to improve the specification and forecasting, for longer periods and more precisely, of performance limiting battlespace conditions wherever our forces operate.

The AF is turning to space systems to provide these improvements. Contributing factors are:

- fewer personnel,
- fewer foreign bases, and
- the emphasis on stand-alone, forward-based, theater weather support systems with limited access to observing sites.

New space systems will benefit from GP programs which provide design parameters to enable satellites to survive the hostile environment of space. Success of the GP Charge Control System aboard Defense Satellite Communication System 3 satellite B7 shows that space environment effects can be mitigated.

Dramatic political and military changes occurring in the former Soviet Union, Eastern Europe, and the Middle East have significantly changed the elements of the potential threat to the US and its allies.

- The AF will need to support simultaneous war-fighting capability in many parts of the world.
- Counter-proliferation now includes biological and chemical as well as nuclear weapon threats.
- Strategic conventional weapons benefit from the Global Positioning System (GPS).
- Development of next generation theater missile defense systems, such as those used against SCUDs in Operation Desert Storm, continues.

Operations in Bosnia emphasize the dependence of tactical operations on satellite communications and weather as in Operation Desert Storm. Problems with visibility, clouds, rain and flooding demonstrate weather's importance at the "sharp end".

Geophysics continues to increase its involvement with operational customers.

- The GEOSpace workstation and software have been demonstrated at the Pentagon Theater Battle Arena and at AF Space Command (AFSPC). GEOSpace can simultaneously show space system orbits and battlespace environment models.
- 50WS at AFSPC will benefit both from integrating multiple existing space weather models into a single Integrated Space Environment Model and from simplifying the operator interface.
- New weather models and weather impact decision aids for the Tactical Forecast System will improve "first in" capability for deployments such as Bosnia and Desert Storm.

Geophysics has responded to the Scientific Advisory Board New World Vistas study. For example, technology will be developed to make theater weather observations from platforms of opportunity such as uninhabited aerial and ground vehicles.

A Geophysics proposal under the Third Millennium Initiative would modify the space environment through electromagnetic emissions. Energy of the right frequency applied in the right place would trigger instabilities and modify the radiation belts, selectively reducing hazards to our space systems.

GP continues to provide more than twenty scientists and engineers as members on twelve Technical Planning Integrated Product Teams (TPIPT's).

A key element of the geophysics long term vision is the integration of the natural environment into the Modeling and Simulation initiative within the DoD.

- Geophysics is developing signature prediction models, based on measurements of real targets and physics-based background models.
- Weapons specific visualizations of targets and backgrounds, including atmospheric effects, can replace traditional flight testing to evaluate electro-optical weapon systems performance.
- Target, background, and atmospheric simulations can
  - stand alone,
  - provide realistic target area scenes for air crew mission rehearsals on the AF Mission Planning System (AFMSS),
  - drive hardware-in-the-loop simulators like the AF Electronic Warfare Effectiveness Simulator (AFEWES), or
  - support broader engagement simulations like the Modeling System for Advanced Investigation of Countermeasures (MOSAIC) or the Digital Infrared Seeker and Missile Simulations (DISAMS).

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

RICHARD R. PAUL
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Technology Executive Officer

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Commander
Phillips Laboratory

CONTENTS

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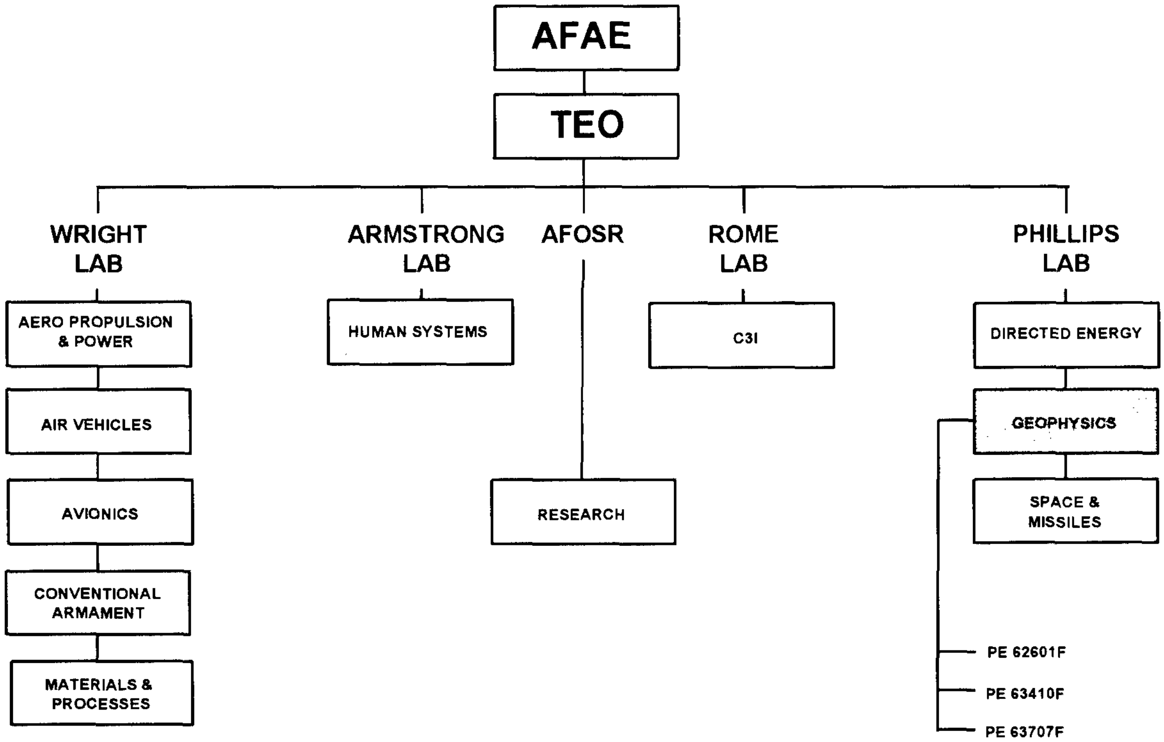

Figure I.1 Air Force S&T Program Structure

INTRODUCTION

BACKGROUND

Geophysics S&T advances Air Force war fighting capabilities by providing technology to define, understand, and control interactions between systems and their environment. These advances are accomplished through environmental programs in the earth, atmospheric, and space environmental sciences. The Geophysics Technology Area (TA) is conducted within the PL Geophysics Directorate. (Figure I.1).

The Geophysics S&T goal is to understand and specify the environmental effects on military systems, mitigate the detrimental effects of the environment, and exploit the properties of the environment for system operation. Because many Air Force systems are adversely impacted by the environment, Geophysics S&T, when applied early in system design, will lead to more affordable, supportable, and reliable systems. The consequences of overlooking adverse environmental interactions early in the development cycle have proved severe. It is cheaper to identify and eliminate adverse effects early than to redesign later.

MAJOR ACCOMPLISHMENTS

The Charge Control System (CCS) was launched 31 Jul 95 on the DSCS-3 satellite B-7 and became fully operational on 19 Dec 95. This system autonomously checks for spacecraft charging, and when it detects a negative threshold of 1.5 kilovolts, it releases sufficient ionized gas to reduce spacecraft charging below the threshold. CCS is number one in the FY97 Advanced Technology Demonstration (ATD) prioritization list from AFSPC (letter of 13 Sep 95 by BGen Lord/XP).

The Parameterized Real-Time Ionospheric Specification Model (PRISM), scheduled for full operation at the 50WS during FY 96, has been shown to be twice as accurate as its predecessor. This specification model uses real-time data to extrapolate ionospheric conditions and the propagation environment worldwide.

An Ionospheric Forecast Model (IFM) was delivered to HQ/ Air Weather Service (AWS) 31 Jan 1996, where it will be transitioned for operational use.

These models are used to predict radio propagation worldwide under any conditions.

The Mid-Course Satellite Experiment (MSX) satellite was successfully launched on 24 Apr 96. MSX provides critically needed data on spatial structure and variability in atmospheric, cloud, and terrain backgrounds and key data on celestial backgrounds.

New analysis of earth background data taken by the Infrared Background Scene Survey (IBSS) experiment shows substantial spatial structure in a mid-wave infrared band important to Missile Defense system design. The narrow-band medium-wave infrared (MWIR) data reinforce an earlier analysis using Cryogenic InfraRed Radiance Instrumentation for Shuttle (CIRRIS) 1A Space Shuttle spectrometer data. The results have been transitioned to the MSX data analysis team.

The Weather Impact Decision Aids (WIDA) program delivered developmental versions of the Night Vision Goggles Operational Weather Software (NOWS) to AFSOC and ACC. Functionality added to these versions included automated weather data ingest, target and obstacles detection, and a probability of seeing the horizon

The Air Combat Targeting/Electro-optical Simulation (ACT/EOS) infrared (IR) scene visualization for air-to-ground targets was further refined and introduced to the Mission Planning Systems Program Office at ESC. Actions are now underway to integrate the visualization capability into the Air Force Mission Support System (AFMSS) as a test and evaluation software module.

A prototype temperate zone artificial intelligence-based regional forecast model has been completed. Independent T&E of the model is underway. It will serve as a "first in" capability for weather support as part of the Tactical Forecast System (TFS).

The Spectral In-band Radiance Images of Targets and Scenes (SPIRITS-AC1) computer code is now being released to the defense community by the JANNAF Signatures Panel. This version includes automated coupling between the component programs, database, flowfield, plume, aircraft body, and terrain and atmospheric environment. The final release version of SPIRITS-AC2 is being prepared. This version supports target modules for the B-52, Air Launched Cruise Missile (ALCM), C-130H, and C-17. Both the C-130H and C-17 codes have been provided to Georgia Tech Research Institute, at advanced request from Program Offices, for use in defensive system simulations and evaluations.

PL conducted ground to air measurements of targets, flare releases, and backgrounds during low altitude passes of the E-8 Joint Stars and the C-17 aircraft in Oct. 95. Excellent data on target, flare, and background sources were measured. The data will be used for future updates of the SPIRITS codes and is available to support defensive system analyses for the Joint Stars program and Air Mobility Command (AMC).

Targeting accuracy improvements were successfully demonstrated with ballistic winds data from ground based Lidar in conjunction with B-52G high altitude bombing exercises. These results have been analyzed to produce technical requirements for an operational airborne B-52 Lidar.

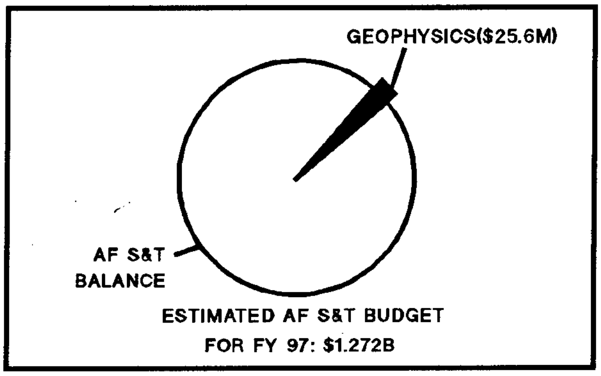

Figure I.2 Geophysics S&T versus AF S&T

AF S&T FUNDING: The Geophysics S&T portion of the Air Force S&T budget is shown in Figure I.2. Funding is based on the FY97 President's Budget Request and actual funding may change based on possible Congressional action. Despite the relatively small funding, Geophysics S&T transitions significant technology to designers and operators of Air Force systems. In FY94, approximately 50 technology transitions were documented.

Geophysics S&T has a program balance that matches current Air Force direction, with the bulk of its funding in exploratory development. The substantial basic research program supports the exploratory development program, and a modest advanced development program provides the technology developed in the exploratory development program to AF customers. Geophysics differs from other technology areas in that the 6.3 program delivers many S&T products directly to customers for operational development, such as the 50WS, rather than to a System Program Office (SPO).

Thrust No.	Title
1.	GEOPHYSICS FOR SPACE OPERATIONS AND COMMUNICATIONS
2.	GEOPHYSICS FOR AIR AND COMBAT OPERATIONS

Figure I.3 Geophysics S&T Thrusts

GEOPHYSICS S&T THRUSTS: Geophysics S&T has two thrusts, listed in Figure I.3

THRUST 1 - GEOPHYSICS FOR SPACE OPERATIONS AND COMMUNICATIONS: **The Space Effects on Air Force Systems Sub-thrust:**

- Defines, models, and predicts the solar and space environment for AF and DOD operations throughout the world,
- Establishes a space forecast capability and develops operational sensors for the measurement of space weather,
- Advances technology in the area of space system environment interactions and accelerates the insertion of new technologies into AF satellite systems through space tests of prototype systems,
- Develops techniques to mitigate environmentally-induced degradation of space systems,
- Supports the AF global responsibility for surveillance and communication, and
- Transmits solar/space environment models and codes to the DOD users through the 50WS.

The Ionospheric Effects on Air Force Systems Sub-thrust:

- Provides real-time ionospheric specification and forecast models, sensors and techniques for operational use at AFSPC.
- Develops the technology to predict when. where and how severely ionospheric disturbances will interrupt operational Air Force systems.
- Specifies atmospheric drag effects for satellite tracking and reentry predictions,
- Measures and develops models of ultraviolet earth backgrounds for designing space-based ionospheric sensors and space surveillance sensors, and
- Develops instrumentation and models to improve Air Force autonomous navigation, inertial testing, precise satellite positioning, and motion sensing systems.

The Optical and Infrared Effects on Air Force Systems Sub-thrust:

- Measures and models infrared and optical wavelength atmospheric, cloud, and terrain background spatial and temporal structure, with particular emphasis on developing new algorithms for Missile Warning and Defense, and Intelligence Surveillance and Reconnaissance Systems,
- Measures and models missile target signatures for accurate detection and typing,
- Measures stellar position and spectral reference sources required for on-board calibration of space- based infrared and optical sensors on surveillance and tracking satellites,
- Develops and validates computer codes to simulate infrared and optical transmissivity and backgrounds, as well as celestial backgrounds, to allow system engineers to optimize the performance of infrared and optical sensors for Missile Warning and Defense, and Intelligence Surveillance and Reconnaissance Systems at minimum cost,
- Provides integrated codes describing infrared and optical backgrounds and transmissivity for real-time battlespace engagement simulations including the effects of weather,
- Develops new electro-optical sensor technologies for target detection and tracking.

THRUST 2 - GEOPHYSICS FOR AIR AND COMBAT OPERATIONS: **The Weather Impact on Air Force Systems Sub- thrust** develops new techniques for measuring, processing, analyzing, modeling, and predicting meteorological properties which impact the Air Force mission. Much of this technology transitions directly to the AWS, which in turn supports the entire Air Force and Army. Emphasis is on developing algorithms for use in designing and operating Air Force systems. Included are:

- Techniques for automated meteorological analysis and display,
- Tactical weather observing and forecasting, and
- Remote sensing and analysis techniques.

The Optical and Infrared Remote Sensing Subthrust develops new environmental monitoring sensor systems for aircraft and ground sites, performs measurements and develops simulations for evaluating the performance of advanced weapon systems, and develops standoff chemical detection capabilities. Much of this technology transitions directly into improved warfighting capabilities of operational commands, such as Air Force Special Operations Command (AFSOC), Air Combat Command (ACC), and AMC. Examples include:

- Remotely sensing of ballistic winds, clouds, aerosols, chemical and biological agents, fugitive emissions, and minor atmospheric species with Lidar.
- Measure and model atmospheric optical turbulence and its effect on laser beams to support next generation laser systems such as the Airborne Laser (ABL).
- Making passive calibrated visible and infrared measurements of aircraft and rocket signatures (such as the B-2, F-117, and the F-22) from the FISTA II airborne platform, and

Developing infrared predictive models of specific targets (such as the C-17A, B-52H, C-130H, and the ALCM) that include all important environmental effects and are used to provide accurate simulations under all operational conditions.

The distribution of Air Force S&T funds in these thrusts is shown in Figure I.4.

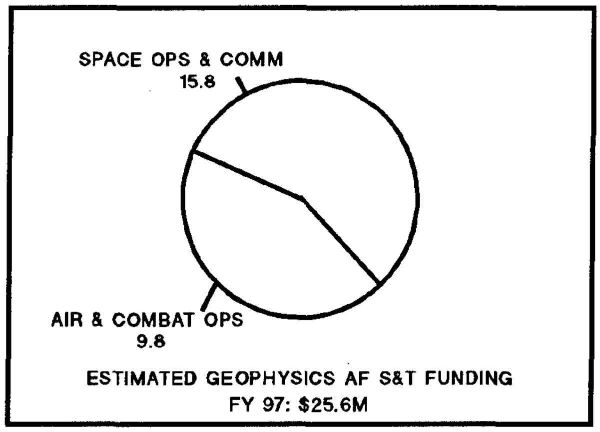

Figure I.4 Geophysics Major Thrusts

RELATIONSHIP TO OTHER TECHNOLOGY PROGRAMS

RELATIONSHIP TO OTHER AF S&T TAs: Geophysics is a pervasive technology that directly interacts with all of the other Air Force S&T technology areas. Geophysics S&T researchers have collaborative programs in Avionics, Command, Control, Communications, and Intelligence (C3I), and Research Technology Areas and cooperative programs in these and in other Technology Areas. Examples include obtaining infrared (IR) signatures and predictive models of aircraft for Air Vehicles; providing space radiation human hazard data to Human Systems; and conducting joint ionospheric RF (radio frequency) propagation experiments with C3I. Geophysics is the leader in working with the Avionics TA from Wright Laboratory in using Lidar to measure winds aloft. Geophysics leads in using Lidar to aid in defining trajectories of bombs. Avionics leads in using Lidar to correct the trajectories of cargo, pallets, and projectiles originating from aircraft.

Within Phillips Lab, Geophysics S&T provides spacecraft environment interaction codes to Space and Missiles TA. Geophysics works with the Lasers and Imaging Directorate in the Directed Energy TA in the characterization of atmospheric optical turbulence and its effects on laser systems and in using Lidars for remote sensing. Directed Energy leads in using Lidar for standoff detection of chemical and biological agents for counter-proliferation purposes.

Geophysics S&T receives extensive support from the Aerospace Engineering Division in the Space and Missiles TA Space Experiments Directorate. Geophysics relies on them to provide engineering, fabrication, and pre- and post-launch support for geophysics rocket, balloon and space experiments.

INDUSTRIAL RESEARCH AND DEVELOPMENT (IRAD): A comparison of the IRAD funds invested by industry in geophysics with the Geophysics Directorate budget is one measure of industrial investment in geophysics technology. Approximately 100 IRAD projects (out of 8000) are in the Geophysics thrust areas. The IRAD funding in geophysics is less than 10% of the total Geophysics S&T funding, underscoring a critical conclusion of the DOD 1994 Laboratory Infrastructure Capabilities Study. If the DOD doesn't support the battlespace Environment S&T, this required "direct support to the warfighter" will not be available, since there is only a very small commercial market for this DOD core technology.

SMALL BUSINESS INNOVATION RESEARCH (SBIR): The SBIR program has helped Geophysics S&T overcome this lack of IRAD. Geophysics S&T has been a strong participant in the SBIR program since its inception and the program has provided the "start- up" capital for innovative ideas that have benefited Geophysics S&T.

COOPERATIVE RESEARCH AND DEVELOPMENT AGREEMENTS (CRDAS): Geophysics S&T also leverages its resources through CRDAs with industry as permitted by the Federal Technology Transfer Act of 1986. Geophysics S&T has seven CRDAs with another being renewed. Geophysics CRDA partners invest more than $500K in these joint programs. CRDAs avoid costs by having industry develop needed technology that other wise would have to be developed by Geophysics S&T.

SPACE TECHNOLOGY INTERDEPENDENCY GROUP (STIG): The space research programs in the Geophysics Directorate are coordinated through the STIG Space Environment and Effects Technical Committee. A current emphasis is the creation of roadmaps that contain research programs underway and planned by the Air Force and National Aeronautical and Space Administration (NASA) primarily and other DOD agencies, where possible. The National Oceanic and Atmospheric Administration (NOAA) and USAF jointly operate the Solar Geophysical Forecast Center, part of the National Center for Environmental Predictions at Boulder. Several cooperative programs with the Navy and NASA are described in the program description.

INTERNATIONAL: The Geophysics Directorate has cooperative research and developments arrangements (Data Exchange Agreements, Memoranda of Understanding, etc.) with seven countries. A recent collaboration was the Shuttle Potential and Return Electron Experiment (SPREE) experiment on the Italian Tethered Satellite System (TSS) flown on the Shuttle. While the deployments of the TSS were unsuccessful, SPREE was an outstanding success since measurements agreed closely with predictive models on both flights.

INTERAGENCY: Geophysics S&T programs are well coordinated with other Federal agencies and by two additional mechanisms within the DOD, in addition to the STIG. The Federal Committee for Meteorological Services and Supporting Research provides coordination and elimination of duplicate activities for the geophysics research being conducted by all Federal agencies. In addition, the Deputy Director of Defense Research and Engineering) (DDR&E) reviews DOD geophysics research at the annual Technical Area Review and Assessment (TARA) Electronics, Sensors, and Battlespace Environment review. Phillips Lab Geophysics Directorate monitors and shares results with the Defense Nuclear Agency (DNA) program on space environment models.

CHANGES FROM LAST YEAR

The Seismology program has been moved from Air Force Materiel Command (AFMC) S&T to DNA. This will allow the Seismology program customers to more effectively champion their programs of interest during funding exercises.

Budget decreases have resulted in the stretch out or cancellation of several programs:

- Development of fully dynamic radiation belt models has been halted.
- The design of the Compact Radiation Effects Satellite (CRES) follow-on experiment has been threatened.
- The Space Weather And Terrestrial Hazards (SWATH) experiment has been put on hold by Ballistic Missile Defense Organization (BMDO). SWATH is a satellite experiment to study the sun and to track space debris in the upper thermosphere of the earth. The coronagraph structure and its mirrors have been built.
- The contrail forecasting program will be reduced.
- A planned program to further evaluate a new GPS radio-occultation technique for global temperature and moisture profiling will be abandoned.

PROJECT RELIANCE: DOD research continues to be reviewed annually for coordination, overlap, and redundancy as part of Project Reliance.

THRUST 1: GEOPHYSICS FOR SPACE OPERATIONS AND COMMUNICATIONS

USER NEEDS

Control and exploitation of space is part of the Air Force mission. Important to achieving this goal is the development of techniques (including sensors and operational models) to accurately specify and forecast the battlespace environment and its effects on Air Force systems and operations. The pervasive nature of these environmental effects is evident.

Space-Based Weather and Environmental Monitoring reflects that weather and environmental monitoring are backbone functions which cut across all commands and all military activities. All commands include weather and environmental monitoring to some extent in a variety of Mission and Functional Area Development Plans. Relevant extracts include:

Missile Defense requires improved definition of target and background signatures to design new systems for missile warning and missile intercept for theater and national missile defense. Technology needs have been identified for near and far term system concepts. These needs include background and target data base measurements and modeling as well as discrimination algorithm development for SBIRS Geosynchronous/High Earth Orbit (GEO/HEO) and SBIRS Low Earth Orbit (LEO) , the Airborne Laser, and more advanced active surveillance systems. The operability of most missile warning and defense systems is limited by background clutter. Measurements and models of atmospheric, cloud, and terrain background which produce clutter are required.

Space Surveillance: Detection, tracking (including orbital changes), identification, and cataloging of all man-made objects in space requires accurate knowledge of stellar calibration sources throughout the visible and infrared spectral region as well as very accurate specification of upper atmosphere neutral density and other environmental conditions. This mission area is studying the utility of identifying and tracking natural space objects for planetary defense against large meteor and asteroid impact

Navigation: The Navigation Systems Modernization Plan requires increased accuracy through carrier phase ambiguity resolution, system and ionosphere range error correction, and multipath reduction algorithms for user equipment as a near term need applicable to all GPS users. GPS systems require increased robustness against signal fades due to scintillation, especially as solar activity increases.

Improved ionospheric modeling is needed to augment GPS by utilizing geosynchronoous satellites such as Advanced MILSATCOM. Similar requirements for improved GPS are also described in the Satellite Control and Intelligence, Surveillance and Reconnaissance (ISR) plans.

Military Satellite Communications: Notes the need to extend communications coverage into the polar region, subject to intense ionospheric disturbances for which no useful model yet exists. There is a need to combat scintillation effects associated with polar and equatorial ionospheric disturbances.

Force Application: There is a need to characterize, predict, and in some cases mitigate the effects of the intense ionization which surrounds very high speed aerospace platforms. A related need is the ability for systems to receive GPS signals during periods of intense ionization.

Satellite Control: Critical RF communication links are susceptible to interruption by environmental disturbances triggered by anomalous solar or geomagnetic space conditions. These disturbances increase the drag on satellites, alter their orbits, can cause high frequency (HF) blackout at high latitudes, alter the frequencies for HF communication links, and create ionospheric scintillations which disturb ultra-high frequency/extremely-high frequency (UHF-EHF) communications.

Theater Battle Management (TBM): Includes improved Over-The-Horizon (OTH) radar for early launch detection and assessment. ACC, North America Air Defense Command and US Southern Command (USSOUTHCOM) identify OTH radar as a solution for current C3I deficiencies; and state that OTH radar will be useful for counter-drug surveillance. Reliable use of OTH radar requires accurate specification and forecasting of the ionosphere, which controls OTH operational performance.

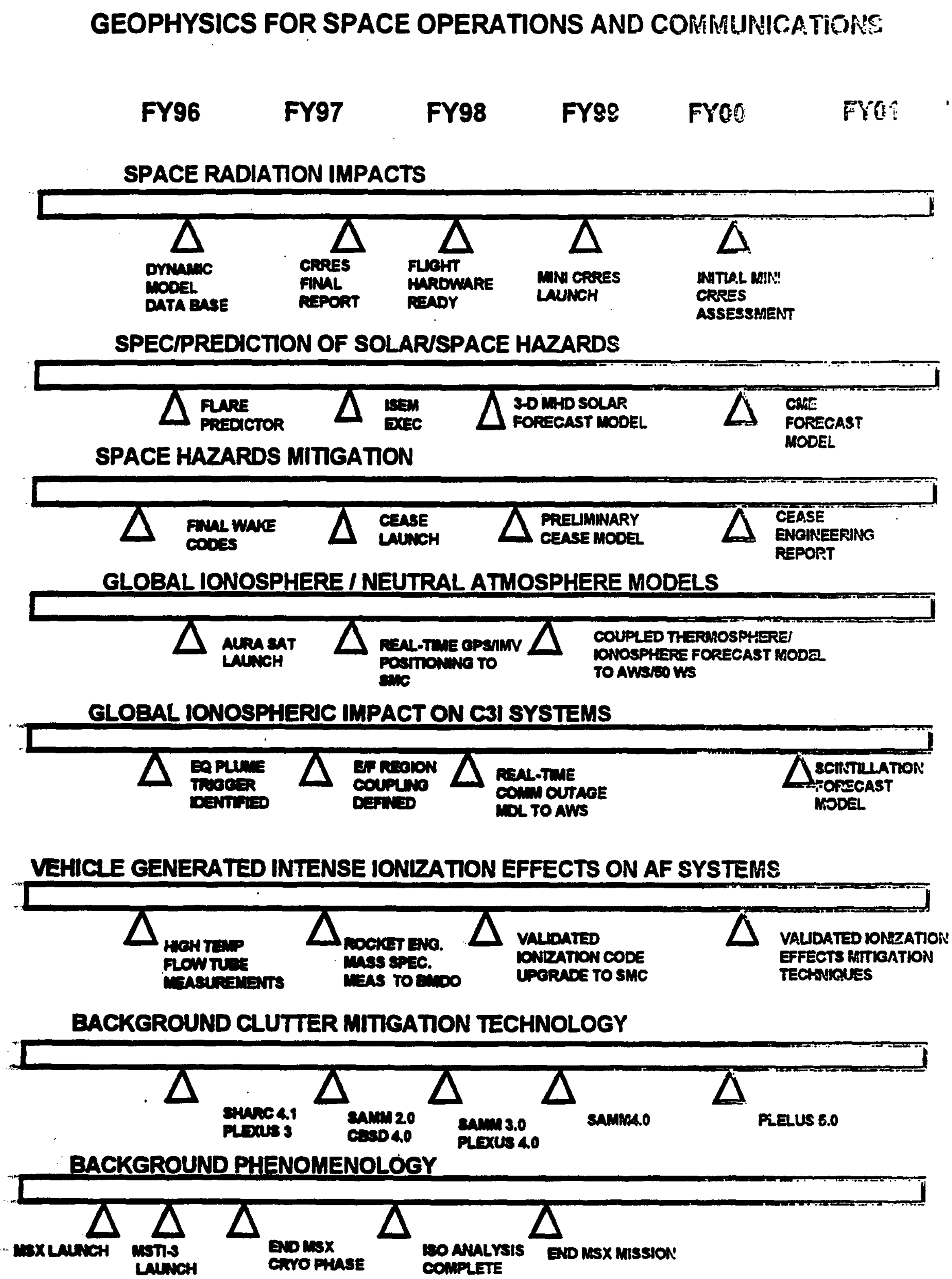

Figure 1.1 Geophysics for Space Operations and Communications

GOALS

Specify and model the hazardous charged particle environment near earth and throughout the magnetosphere so designers can achieve required performance with minimum life-cycle costs. Measure key solar and interplanetary parameters for specification and forecast models to minimize severe space system degradation or failure.

Obtain a global, real-time, capability to accurately specify and forecast the state of the ionosphere and neutral atmosphere including the ability to provide timely warning of when, and how severely, ionospheric disturbances will disrupt C3I systems. Investigate the effect of ionospheric scintillation which degrades GPS accuracy or availability.

Specify and predict the earth's upper atmosphere neutral density with accuracies to meet operational requirements for satellite tracking, reentry predictions, detection of orbital changes, determination of satellite lifetimes and on-board fuel requirements, and space debris hazard assessments.

Combine the separate energetic charged particle, ionospheric, and neutral density models into an Integrated Space Environment Model system that monitors the environment in which space systems operate and warns of hazards to space systems and on earth, for example, power transmission grids.

Characterize and be able to predict the intense ionization around hypervelocity platforms; quantify their effects on GPS radio signals; and develop techniques to control ionization to alleviate radio blackout and increase guidance accuracy.

Characterize and measure the infrared and optical wavelength signatures of backgrounds and targets (including missile plumes) needed to discriminate target from their backgrounds.

Develop/validate computer codes to simulate infrared and optical atmospheric transmissions and backgrounds and celestial backgrounds to allow designers to optimize the performance of infrared and optical sensors for surveillance, tracking, and interceptor systems at minimum cost.

MAJOR ACCOMPLISHMENTS

The CCS was launched 31 Jul 95 on the DSCS-3 satellite E-7 and became fully operational on 19 Dec 95. This system autonomously checks for spacecraft charging, and when it detects a negative threshold of 1.5 kilovolts, it releases sufficient ionized gas to reduce spacecraft charging below the threshold. CCS is number one in the FY97 ATD prioritization list from AFSPC (letter of 13 Sep 95 by BGen Lord/XP).

SPREE was launched for a second time on the Space Shuttle, STS-75 on 22 Feb 96. The purpose of this experiment was to provide a detailed picture of the electrical structure about large space structures as a tethered satellite was deployed and retrieved 20 km from the Shuttle. The program is a test for a potential new power source and for new ways to investigate the upper atmosphere. The major objectives of the SPREE experiment were achieved despite the separation and loss of the tethered satellite after 19 of the 20 kilometers of tether were deployed.

The second flight of the Charging Hazards And Wake Studies (CHAWS) experiment, a subsystem on the University of Houston's Wake Shield Facility, a four-meter free-flying disk, flew on Space Shuttle Endeavor's mission of 7-18 Sep 95, STS-69. The instrument complement collects ions in the ram and wake directions. The data will help design spacecraft codes concerning the electrical structures about large vehicles in space.

The Space Waves Interactions with Plasmas Experiment (SWIPE) was launched aboard the Oedipus-C rocket into an auroral arc from the Poker Flat Research Range in Alaska, on 7 Nov 95. A joint venture with the Canadian Space Agency and NASA, the tethered mother-daughter payload reached separations up to 1000 km in testing how the space environment impacts transmitter power-loss, attenuation, antenna sheath structure, and radiated signal strength for HF communications.

The Flare Genesis payload flew in a circumpolar balloon flight about Antarctica during 7-26 Jan 96. A joint effort of Phillips laboratory, NASA, National Science Foundation, and the Applied Physics Laboratory of Johns Hopkins University, the main payload was the second largest solar telescope in the world. The mission was to fix on the sun for a constant period of time during austral summer to obtain solar data to improve our ability to forewarn of solar disturbances likely to generate geomagnetic storms which wreak havoc with satellite systems from the energetic particles created and which cause neutral density (satellite orbit) changes. The data tapes from the flight were recovered and are undergoing a preliminary evaluation.

A strong correlation was found between solar wind velocity and the angular distance of the wind from coronal holes using solar wind data from the Ulysses satellite and measurements of Fe XIV coronal emissions made at the Sacramento Peak Observatory. This information should improve forecasts of geomagnetic storms whose origin is coronal holes.

The GEOSpace 1.1 (version beta) code was delivered and installed at 50WS on 8 Sep 95. GEOSpace provides a user-friendly graphical interface to a variety of near-Earth space environment models and applications with an emphasis on three-dimensional visualization. This code includes electron (CRRESELE), proton (CRRESPRO) and dosage (CRRESRAD) codes built from the data base accumulated with the Combined Release and Radiation Effect Satellite (CRRES), plus the PRISM, the Wide-Band Scintillation Model (WBMOD), a three-dimensional ionospheric ray tracing model, an auroral particle model, and a variety of external magnetic field models. GEOSpace basically is the first version of an Integrated Space Environment Model (ISEM). GEOSpace was also demonstrated in the Battlespace Arena at the Pentagon.

The PRISM, scheduled for full operation at the 50WS during FY 96, has been shown to be twice as accurate as the ionospheric model it replaces. This specification model uses real-time data to extrapolate ionospheric conditions and the propagation environment worldwide. An IFM was delivered to HQ/AWS 31 Jan 1996, where it will be transitioned for operational use. These models are used to predict radio propagation worldwide under any conditions.

A Thermosphere Forecast Model (TFM) effort was initiated for specifying global neutral densities and for coupling with an IFM. The goals are to specify and (ultimately) forecast neutral densities to within 5% to satisfy requirements for accurate models of satellite drag and to provide accurate winds and composition to the Coupled Ionosphere Thermosphere Forecast Model (CITFM) to be transitioned to 50WS.

The operational WBMOD was improved by an order of magnitude and delivered to 50WS to warn operators of ionospheric scintillations that seriously disrupt C3I systems.

A Coupled Ionospheric Scintillation Model (CISM) was initiated for nowcasting equatorial scintillation on a global basis, based on the electron density model, satellite data, irregularity model and scattering theories. CISM will be completed in FY98 and the products will include amplitude and phase scintillation at any frequency.

PL provided special scintillation support to investigate SATCOM anomalies affecting USAF operations in San Vito, Italy. When tactical forces encounter impaired communications, it is essential to quickly determine whether the problem is due to the environment, equipment, or the enemy. PL engineers were able to remotely link with an AF digital ionosonde in San Vito and determine that the ionospheric environment did not cause the interference. Personnel from 50WS and PL deployed to San Vito, isolated the cause of the disruptions to equipment and suggested solutions.

A third scintillation warning system has been deployed for nowcasting and providing short-term forecasts of 250 Mhz scintillation over a specified region. The capability will be increased to frequencies that affect GPS satellites. The scintillation warning systems can be accessed by PL for research purposes and by AFSPC controllers for real time specification of ionospheric disturbances that degrade satellite communications.

Efforts supporting the Ionospheric Measuring System (IMS) for Sacramento Air Logistic Center resulted in the installation and successful calibration of IMS sensors supporting space surveillance radars at Otis Air National Guard Base, Croughton Air Base, United Kingdom and Thule Air Base, Greenland. High accuracy remote calibration of these IMS sites is being maintained using a unique process developed at PL/GPI. Support was provided to 50WS and Sacramento Air Logistic Center for baselining two Digisonde sites as part of the Digisonde network upgrade program.

Under the High-frequency Active Auroral Research Program (HAARP), research was initiated to assess the viability of using ionospherically generated ULF/ELF/VLF radio waves for the detection of underground tunnels and structures.

The effects of intense vehicle-generated ionization on GPS transmission were successfully measured in the Calspan 96" shock tunnel under realistic reentry conditions (Mach 14) for a full-scale reentry body as functions of angle-of-attack and GPS broadcast angle. The data will also be used to validate AF ionization prediction codes needed for flight tests. In a related activity, ion reaction kinetics measurements were extended from 1300 K to 1700 K (the highest temperatures ever achieved) using a one-of-a-kind laboratory apparatus equipped with a furnace. The high temperature data are required for the AF ionization prediction codes for characterizing the ionization which degrades system performance.

The MSX satellite was successfully launched on 24 Apr 96. MSX provides critically needed data on spatial structure and variability in atmospheric, cloud, and terrain backgrounds and key data on celestial backgrounds.

Under the SBIRS Phenomenology Exploitation Program (PEP), a systematic assessment of the accuracy of the codes used to generate spatially structured atmospheric, cloud, and terrain background scenes for Missile Warning and Missile Defense systems engineering was performed for the SBIRS SPO.

Prototype codes to generate two-dimensional images of IR backgrounds containing non-stationary stochastic structure have been developed to support the performance and cost optimization of Missile Warning and Defense, Intelligence and Theater Missile Defense interceptor systems. The Synthetic High Altitude Radiance (SHARC) code provides in-band mean radiance and the statistical structure parameters. The Synthetic Atmospheric Structure (SASS) code and SHARC Image Generator (SIG) codes turn the SHARC 4 outputs into scenes containing spatial structure. Synthetic scenes generated using SHARC and SIG have been transitioned to the MSX and MSTI-3 mission planning teams.

The SBIRS Toolkit, combining the CLDSIM and GENESSIS codes for simulating cloud and terrain background scenes observed from space platforms, has been developed and released to the SBIRS SPO and contractors.

The Celestial Background Scene Descriptor (CBSD) has been upgraded by providing diffuse zodiacal, asteroid, moon, planet, and point galactic source models covering the 0.1-49 micron spectral region. An infrared astrometric catalog containing about 100,000 stars has been incorporated in CBSD.

A modular non-interactive version of the Phillips Laboratory Expert Unified Simulator (PLEXUS), providing single point access to Phillips Laboratory background and transmission codes, was delivered for inclusion in the Joint Modeling and Simulation System (J-MASS).

Infrared and optical background and transmission codes were developed and distributed to support SMC and BMDO Missile Warning, Missile Defense, Intelligence and interceptor systems including SBIRS GEO/HEO, SBIRS LEO (also known as the Space Missile Tracking System), the Ground Based Interceptor, and AWACS Eagle:

- The SBIRS Tool Kit for calculating cloud and terrain background scenes observed from satellite platforms.
- The Moderate Spectral Atmospheric Radiance and Transmittance (MOSART) 1.41 code for calculating ultraviolet (UV) to millimeter wave transmission and backgrounds in the lower atmosphere.
- The SHARC and MODTRAN Merged (SAMM) 1.0 code for calculating all-altitude background spectra and in-band radiance altitude profiles.
- The PLEXUS 2.0 code providing expert system access to the Fast Atmospheric Signature Code (FASCODE), Moderate Resolution Transmission (MODTRAN), SHARC, and the CBSD codes.

New analysis of earth background data taken by the IBSS experiment shows substantial spatial structure in a mid-wave infrared band important to Missile Defense system design. The narrow-band MWIR data reinforce an earlier analysis of CIRRIS 1A Space Shuttle spectrometer data. The results have been transitioned to the MSX and the MSTI data analysis teams which are preparing to make definitive measurements on background clutter for the SBIRS program.

Laboratory measurements were performed to transition optical and infrared atmospheric background data from several highly successful space Shuttle and rocket-borne experiments into background codes for space systems engineering support.

The Infrared Space Observatory (ISO) was launched in FY96 and will provide celestial background data to validate and upgrade the component models in the CBSD.

CHANGES FROM LAST YEAR

The development of fully dynamic radiation belt models has been halted due to insufficient PE62601F funds.

Declining PE62601F fund levels threatens to delay the design of the CRES follow-on experiment.

AFSPC decided to upgrade the optical solar sensors in the Solar Electro-Optical Network (SEON). Funding of $33k has been provided to GPSS for the design of an Improved Solar Optical Observing Network (ISOON). The source of funding to build the ISOON prototype has not been determined.

SWATH has been put on hold by BMDO. SWATH is a satellite experiment to study the sun and to track space debris in the upper thermosphere of the earth. The coronagraph structure and its mirrors have been built.

The Atmospheric Density Satellite (ADS) lost during a 1994 launch due to rocket failure, was resubmitted for launch with a planned flight during solar maximum in 1999-2001. More than 70% of the AF payload is already available from flight spares.

Deployment of a Remote Access Scintillation Warning System (RASWS) to Saudi Arabia was delayed pending identification of the best site by AFSPC; deployment is now anticipated for FY97. In a related activity, after discussions with AFSPC, the global C3I outage warning system network and display was restructured to allow development of a regional network and real-time display of the outage regions with testing beginning in FY96.

Direct support for the SBIRS SPO and contractors is now provided by participation in the SBIRS Phenomenology Exploitation Program (PEP). Key objectives of the SBIRS PEP are measuring spatial structure in infrared backgrounds producing stressing levels of background-induced clutter, assessing and upgrading (if necessary) the atmospheric, cloud, and terrain background codes used to extrapolate measured backgrounds to the full system design trade space, and transitioning the background data and codes to the SBIRS SPO and contractors.

Under the Air Force Office of Scientific Research-sponsored "Signatures of Upwards Atmospheric Discharges" new initiative, measurements of infrared, optical, RF and radar signatures of high altitude (50-90 km) discharges associated with large scale thunderstorms are made using ground, aircraft, and satellite based sensors. The signature data are correlated with data from operational Air Force satellites and modeled to improve the operability of Missile Defense and nuclear event detection systems.

The range of applicability of the MODTRAN code, which is the fast-running, Government standard code for calculating atmospheric transmission and backgrounds in the lower atmosphere, is being upgraded to meet new Intelligence, Surveillance, and Reconnaissance requirements.

MILESTONES

Advances in specifying and modeling the static and dynamic behavior of the Earth's radiation belts are essential for AF/DOD space systems designs and operations.

Radiation belt products include:

- Energetic particle models and simulations to be transitioned to the SMC and to 50WS in FY97,
- Design of a follow-on CRES payload to characterize high energy particles (greater than 1 MeV) will be completed by late FY97 if funding permits.
- Quasi-dynamic radiation models will be transitioned to SMC and industry in FY98, and

Advanced technology products include:

- The Digital Ion Drift Meter (DIDM) is scheduled for launch on STEP 4 during Jun 97. This device will be a test new technologies for environmental sensing. Ions with energies less than 1 eV will be measured. This lighter, more capable instrument eventually should replace the comparable instrument on Defense Meteorological Satellite Program (DMSP) vehicles. The German government has expressed an interest in flying DIDM on their CHAMP satellite.
- The Compact Environmental Anomaly Sensor (CEASE) has a signed MOA with the STP to fly on TSX-5 which is planned to be launched in October, 1998. A second CEASE, at the behest of the British Defense Agency, may get a ride on the Space Technology Research Vehicle (STRV) - 1 c/d during July, 1998. CEASE autonomously warns satellite operators of environmental conditions likely to cause anomalous spacecraft operations.
- New charging algorithms to assess spacecraft-plasma interactions (FY97), and

- Mechanisms affecting the performance of space-based radio transmissions and receptions, based on the SWIPE mission, will be characterized by FY98

Three space sensors which provide data for operational space weather models will be launched with the next DMSP satellite in January, 1998. The sensors will measure at altitude, 840 km, ionospheric concentrations and temperature, auroral particle fluxes and the earth's magnetic field.

The Small On-Board Environmental Diagnostic Sensors (SOBEDS) should be built by the end of FY98. This key complement of instruments for the CRES follow-on satellite will measure high energy electrons (1-30 MeV) and protons (1-100 MeV) responsible for radiation dose effects, medium energy ions and elections (10-500 keV) which cause surface and interior charging, the thermal plasma which is important to exposed high voltages, electric and magnetic fields which control local plasma dynamics and the deposition of contaminants on the spacecraft.

As identified in the AF Weather Mission Support Plan, in the AFSPC Space Based Environmental Monitoring Mission Area Plan (MAP) and the Force Enhancement Navigation MAP, there are requirements for the development of improved operational Space Environment models. An "Advanced Coupled Space Environment Forecast Models" ATD Technology Transition plan has been approved which details the development and delivery of operational models to 50 WS over the next 5 years. These models include, among others, a CITFM to be delivered in FY97, an Advanced Coupled Magnetospheric Model (ACMM) , a CISM and a Solar Prediction Model (SPM) all to be delivered to HQ/AWS in FY98.

Data from ground- and space-based sensors will be used in FY96-FY99 to update specifications of the ionosphere, neutral atmosphere, and space-debris environments.

- During FY96 the IFM will be transitioned to 50WS and will be operational in FY97. The PRISM ionospheric specification model will be extended to geosynchronous altitudes (22,000 km) in FY96 and will be coupled with a thermosphere model for delivery to HQ AWS in FY97.
- In support of AFSPC and 50WS customers, the global HF model called IONCAP has been modified and will be operational at 50 WS in FY96. It uses the operational PRISM output to provide hourly HF forecasts, globally to all DOD HF customers. The current capability are HF forecasts every 6 hours.
- Owing to loss of the ADS neutral density satellite in the launch failure of the STEP-1 mission in FY94, new ADS sensors and hardware will be developed during FY96-FY99, with re-launch of a new atmospheric-density satellite in FY00 (during solar max). The goal is to provide the capability to specify densities between 160-500 km with less than 5% error.
- During FY97 a real-time regional scintillation specification system will be completed and delivered to AFSPC.
- As an intermediate product of the CISM, a forecast tool for the onset of equatorial scintillation on a global scale based on satellite data will be provided to 50WS.

The fourth Ionospheric Measuring System (IMS) sensor is scheduled for deployment to Shemya, AK where it will support 50WS' ionospheric corrections for the Cobra Dane radar. A direct operational interface from the IMS to deliver real-time updates to the radar is being planned for FY97. The fifth IMS installation is scheduled for Diego Garcia in FY96-FY97.

HAARP's Developmental Prototype (DP) transmitting array at Gakona, Alaska will be augmented by the acquisition of up to 30 additional transmitter units by the end of FY97. The total radiated power will increase from the present 360 kW to 960 kW, providing the US with a facility having unique capabilities for the scientific study of the auroral ionosphere, for the assessment of both natural and artificial ionospheric disturbances on military and civilian radio systems, and for determining the usefulness of ionospherically generated ULF/ELF/VLF radio waves for the detection of underground tunnels and structures.

The AF codes which predict the deleterious effects of intense vehicle-generated ionization, including degradation and loss of GPS transmission, will be upgraded and validated in FY97. Chemical and other techniques to mitigate deleterious ionization effects on

GPS transmission will be tested and evaluated in FY97-99.

Data on spatial structure in infrared and optical atmospheric, cloud, and terrain backgrounds will be collected from satellite platforms. Codes to extrapolate the measured background data to the full range of Missile Warning and Defense and Intelligence system design trade spaces will be upgraded and validated. Laboratory measurements will be performed to transition the space data into improved models and codes.

- The MSTI-3 satellite will be launched in FY96 to provide critically needed background data in bandpasses complementary to MSX.
  - During FY96-01 MSX and MSTI-3 data will be used to upgrade and validate the models of spatial structure and variability in infrared and optical backgrounds. The data will be transitioned to the SHARC, SAMM, and SBIRS Toolkit codes. Celestial background data will be transitioned to CBSD to provide stellar onboard calibration sources for advanced space-based surveillance and tracking systems. MSX and MSTI-3 data sets will be archived along with simultaneous satellite, aircraft, and Lidar truth data at the Phillips Laboratory Data Analysis Facility for analysis and distribution to the SBIRS SPO and contractors.
- Major upgrades in the capabilities of the atmospheric infrared and optical background and transmission codes will be made during FY96-01 and transitioned to SMC and Aeronautics Systems Center (ASC).
  - Key new infrared and optical background data from satellite, space shuttle, and rocket-borne experiments (MSX, MSTI-3, CIRRIS 1A, IBSS, SKIRT I, II, and EXcitation by Electron DEposition (EXCEDE) III) will be transitioned to the infrared background codes in FY96-98.
  - Beta versions of the SHARC 4, SIG, and SASS codes used to generate background scenes containing accurate spatial structure will be released in FY96. The structure models will be assessed and upgraded using MSX and MSTI-3 data in FY96-98.
  - The SAMM 2 code, providing a seamless description of spatially structured atmospheric backgrounds, will be released in FY97. The code will be upgraded as the constituent codes (SHARC, MODTRAN, MOSART, SIG, and SASS) are upgraded. The capabilities of SAMM will be extended into the UV and millimeter wavelength regions in FY98.
  - The MODTRAN 4 code providing transmissivity and backgrounds in the lower atmosphere including highly flexible cloud descriptors and diffuse transmissivity though clouds will be released in FY96 and upgraded in FY97. The FASE (FASCODE for the Environment) for use on high speed, vectorized computers will be released in FY96.
- The PLEXUS code, which provides single point access with expert system support for all of the atmospheric background and transmission codes, will be updated yearly as the constituent codes are upgraded and transitioned to SMC and ASC during FY96-01.
  - PLEXUS 3 with an interactive graphical user interface attached to a separable non-interactive, platform-independent core will be delivered in FY96 to support both desktop and large scale simulation code (including J-MASS and SSGM) users.
  - PLEXUS will be upgraded during FY97-99 to permit full dynamic environmental (weather) time step computational ability from ground to space and across the spectrum from RF to ultraviolet wavelengths.
- Laboratory and theoretical investigations of infrared emissions arising from high altitude missile fuel vents and from hypervelocity collisions between atmospheric species will be performed. The results will be transitioned into fuel vent signature and background codes during FY96-98 to interpret space observations of fuel vents and background signature enhancements.

THRUST 2: GEOPHYSICS FOR AIR AND COMBAT OPERATIONS

USER NEEDS

The atmosphere plays a key role in the design and utilization of almost all Air Force systems and in their operational implementation. Therefore, User Needs related to this Thrust are pervasive and can be identified in many Mission Area Plans and Mission Support Plans and in product center Development Plans. There are three sets of documents where atmospheric research requirements are explicitly described:

1. AF Major Command MAPs, the AF Mission Support Plan and the related Electronics Systems Center (ESC) Weather Development Plan. The prioritized Technology Needs identified in this process are as follows:

- Cloud Analysis and Forecasting Models; substantial improvement in spatial and temporal accuracy,
- Surface Weather Parameter Analysis and Forecasting Models; emphasis on visibility,
- Hazard Analysis and Forecasting Models: emphasis on turbulence, icing, and thunderstorms,
- Tactical Environmental Sensing; specific weather parameters in data-sparse regions of DoD interest,
- Atmospheric Models; forecast models focused on parameters for air-base and battlefield support,
- Weather Impact Decision Aids; electro-optical sensor-specific algorithms which accurately predict system performance as a function of weather conditions
- Weather Radar Automated Forecasting Techniques; algorithms/models to infer severe aviation weather hazards from NEXRAD (WSR-88D) Doppler radar
- Mid- and Long-Term Applications Modeling; develop application models for centralized weather forecasting related to TBM, strategic enhancement/projection and National Program customers
- Advanced Climatological Modeling; climate spreading techniques needed to develop global climatologies including data sparse/void regions

2. The AFSPC MAP entitled, Information Dominance and the related SMC Development Plan. The Weather Concepts identified in this process are as follows:

- National Polar Orbiting Environmental Satellite Sensors (NPOESS)
- DMSP Block V Sensors
- Small Tactical Terminals
- Wind Profile Sensor Suite
- Light Detection and Ranging (Lidar)
- Millimeter Wave Radar
- Alternative Weather Systems

Technical Needs are identified for each of these Weather Concepts. These concepts require new sensor concepts and the related retrieval algorithms and software development to convert electromagnetic signals into the required weather and atmospheric parameters.

3. The AFSPC MAP entitled, Space Superiority and the related SMC Development Plan. The Range Standardization and Automation (Phase II) program in the development plan requires improved weather data collection. Technology Needs include improved space-launch weather support by the forecasting of both natural and triggered lightning.

There are also weather related requirements in the Global Mobility and Air Superiority MA Plans which have been integrated into the Weather Technology Needs.

Lidar for remote sensing holds great promise for meeting the following needs:

- The 1992 AFMC Laser Mission Study identified the need to accurately measure winds aloft between an aircraft and the ground to aid in defin-

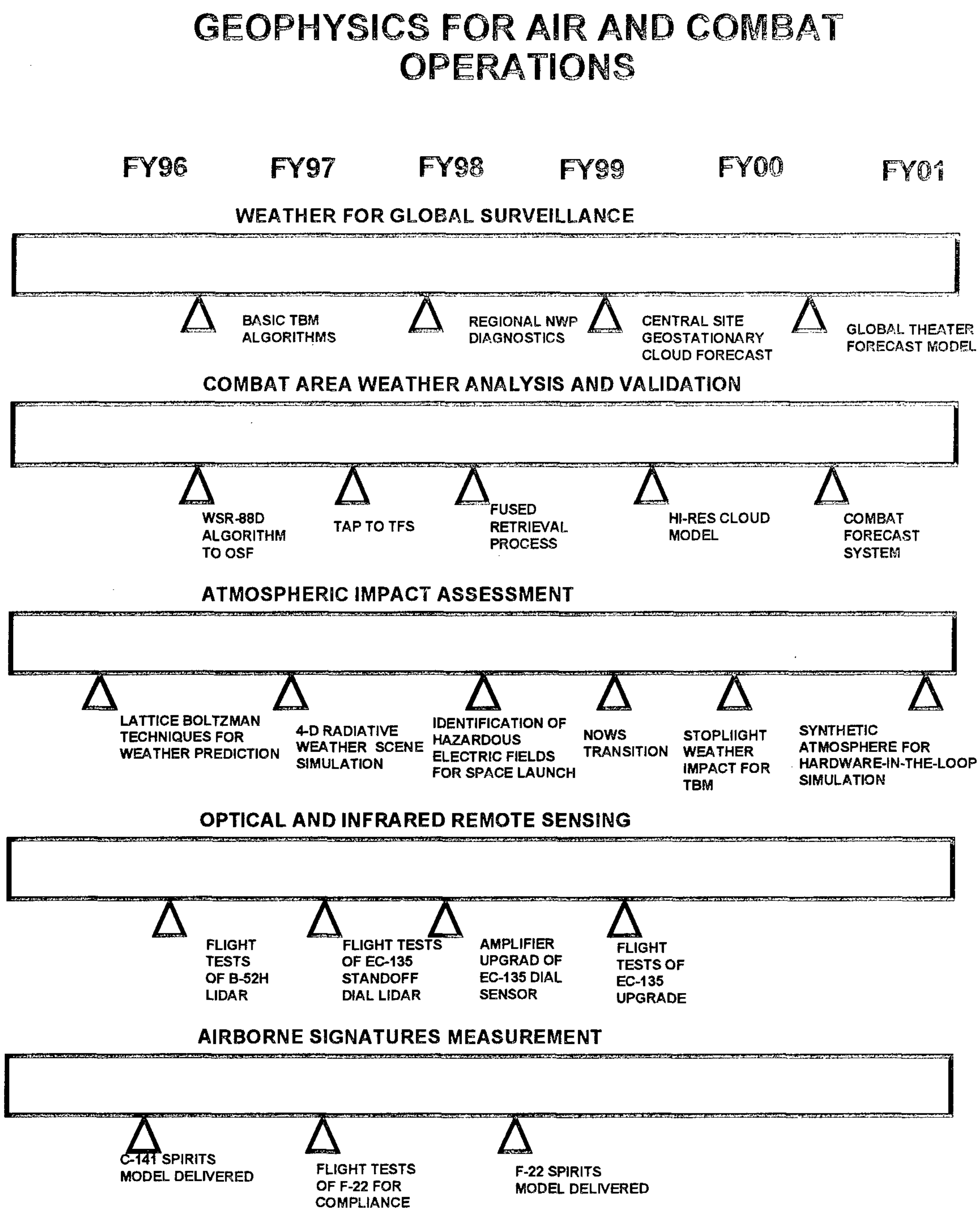

Figure 2.1 Geophysics for Air and Combat Operations

ing trajectories of bombs, cargo pallets, and projectiles fired from the aircraft,

- ACC, AFSOC, and AMC expressed active interest in the development of techniques for the remote sensing of winds that affect ballistic trajectories. Measuring winds from aircraft using Lidar is an intermediate step towards the ultimate objective of measuring winds aloft from NPOESS and other weather satellites,

- DOD and several intelligence agencies support the application of Lidar for detection of chemical and biological agents. The system would be used for theater stand-off detection and for detecting fugitive emissions associated with production of these agents for non-proliferation monitoring and treaty compliance, and

- Memorandum from the Joint Chiefs of Staff 154-86 identifies many requirements for the remote sensing of the environment from space. Lidar can supply capabilities identified there that cannot be attained through passive techniques.

Airborne Signature Measurements: Designers and developers of aircraft and missile systems have important needs for airborne measurements and support for model development. With the installation of improved visible and infrared instrumentation equipment into the new FISTA 2 platform, these and other short and long term measurement and modeling needs of the AF, Defense Advanced Research Projects Agency (DARPA), and BMDO can be met. These needs include:

- F-22 Test Facility Requirements Document (TFRD), CDRL A085, May 1993 to support infrared specification compliance. ASC has tasked the FISTA program to conduct IR measurements and support IR modeling of the F-22 to establish an accurate IR simulation capability of the new aircraft. This will also enable threat, vulnerability, and survivability studies to be performed and will minimize the need for flight testing.
- AMC needs, for C-17 Airlift Defensive Systems, to develop a validated IR simulation model of the C-17 for testing of defensive flare systems. Development of simulation capability as early as possible in development and operational testing can greatly minimize costs by optimization of test planning and procedures.
- IR simulation is in extensive use by ACC as an aid in low observability threat analysis. Accurate and verified simulation capability supplied by the SPIRITS codes allows maximum optimization of threat analysis before testing and operational verification on flight vehicles.
- The AF Information Warfare Center (AFIWC) requires a comprehensive measurement/model data base (PMD 0943(3)/28021F) on all non-foreign weapon systems. Our airborne measurements and model development are needed to eliminate critical deficiencies in their database.

GOALS

The goals of this thrust, derived from the needs cited above include:

- Exploit satellite-based remote sensing to obtain continuous, worldwide coverage and avoid data denial by unfriendly countries.
- Combine advanced multi-satellite cloud retrieval techniques into cloud analysis models for centralized and theater weather centers.
- Generate accurate and reliable short-term (0-6 hours) high resolution cloud forecasts globally.
- Develop new Weather Impact Decision Aid software in support of all weather-sensitive AF systems, such as electro-optical (EO) smart weapon systems, reconnaissance and surveillance systems and mission planning.
- Support mission planning and execution decisions based on timely and accurate weather information.
- Develop accurate and validated cloud and weather simulation for any world-wide location to support acquisition, training and war-gaming.
- Develop techniques to reliably forecast conditions for triggered lightning to increase missile launch availability.
- Develop optical turbulence measurements and models for performance specification and prediction of laser system performance such as Lidars and laser weapons.
- Measure of atmospheric wind fields by ground-based and airborne Lidar systems for ballistic wind applications.
- Develop Lidar technology for stand-off detection of chemical and biological agents and for verification of chemical and biological treaty compliance.
- Develop transmitter and signal processing Lidar hardware for space-borne wind sensing.
- Acquire high fidelity, quantitative airborne target and background measurements for target signature phenomenology determination.
- Extend our target modeling capability to include the visible and ultraviolet spectral regions, more accurately model reflective signatures, such as

sun glints, and more accurately model low observable surfaces properties and special coatings.

- Interface our phenomenology based predictive models into existing or developmental engagement models, providing accurate target and background signatures for a wide variety of operational and environmental conditions.

MAJOR ACCOMPLISHMENTS

A prototype temperate zone artificial intelligence-based regional forecast model has been completed. Independent T&E of the model is underway. It will serve as a "first in" capability for weather support as part of the TFS. A companion model for tropical zone application is under development.

A comprehensive field program was successfully conducted as part of a contrail research and forecasting study. Over 200 balloon-borne profiles of temperature and water vapor distribution were obtained, along with special satellite and aircraft measurements, to correlate with over 600 documented contrail events. These data are being used to validate and improve weather forecast models and contrail diagnostic algorithms.

Water vapor measurements from the DMSP SSM/T-2 sounder have been adapted through an algorithm to locate regions of precipitation occurrence and upper tropospheric humidity. The results provide more robust depiction of precipitation and high level moisture than can be obtained from other satellite sensing options.

An enhanced set of diagnostic algorithms to infer cloud cover from numerical weather prediction forecast fields has been developed. They have been demonstrated superior to longer range cloud forecasts using the AF's operational method. The cloud forecast requirements of the Global/Theater Weather Analysis and Prediction System's Operational Requirements Document (GTWAPS ORD) will be satisfied with and adaptation presently underway of these algorithms.

The Weather Impact Decision Aids (WIDA) program delivered developmental versions of the Night Vision Goggles Operational Weather Software (NOWS) to AFSOC and ACC. Functionality added to these versions included automated weather data ingest, target and obstacles detection, and a probability of seeing the horizon. Further coordination with AFSOC and ACC is continuing in an effort to refine future new capabilities required.

The Air Combat Targeting/Electro-optical Simulation (ACT/EOS) IR scene visualization for air-to-ground targets was further refined and introduced to the Mission Planning Systems Program Office at ESC. Actions are now underway to integrate the visualization capability into the Air Force Mission Support System (AFMSS) as a test and evaluation software module. Validation of the ACT/EOS physical models suite continues at Hanscom AFB. Arrangements have been made to also validate the models and IR scene visualization at Eglin AFB, FL and the Weather Test Facility, Otis ANGB, MA.

Data from eight weather satellites were used to construct a cloud climatology for every hour over the entire earth at 5 km resolution for the period 1 February 1994 through 31 January 1995. The 365 exabyte tapes were delivered to national technical means (NTM) in September 1995.

In support of launch operations at the national ranges, PL scientists worked with other experts to modify the lightning Launch Commit Criteria (LCC) so as to reduce the number of delays and scrubs due to lightning at Kennedy Space Center (KSC) and Cape Canaveral Air Force Station (CCAFS). A "Feasibility Analysis for Measuring Electric Field Aloft", provided to the joint AFMC/AFSPC Range Standardization and Automation (RSA) program, showed that the use of an Airborne Field Mill Aircraft at KSC/CCAFS would save over $1M/year.

In response to a Defense Modeling and Simulation Office (DMSO) requirement and funding, a comprehensive, tri-service survey was conducted to determine the requirements to include weather parameters and environmental effects in DoD simulations for system design, training, war-gaming and analyses. The survey identified the priority of parameters needed and their spatial and temporal scales. A second survey documented currently available environmental simulation capabilities and models, and concluded with recommendations on overcoming the shortfalls between requirements and current capabilities.

PL successfully demonstrated the ability to simulate high fidelity, physically realistic, 4-dimensional cumulus cloud for use in DoD system design, simulation, and training applications for transition to

Tactical Air Control Center Simulation Facility (TACCSF), ABL, Theater Battle Arena, WIDA.

Targeting accuracy improvements were successfully demonstrated with ballistic winds data from ground based Lidar in conjunction with B-52G high altitude bombing exercises. The field measurements were completed, including joint measurements between the ground based and airborne Lidars. These results have been analyzed to produce technical requirements for an operational airborne B-52 Lidar.

SPIRITS Aircraft 1 Version (SPIRITS-AC1) was completed and has been released to the defense community by the JAN Signatures Panel after considerable delays over approval associated with release agreements. This version of SPIRITS has many advances over the old SPIRITS-4.2 including automated coupling between the component programs, database, flowfield, plume, aircraft body, and terrain and atmospheric environment. SPIRITS Aircraft 2 Version (SPIRITS-AC2) has now been frozen and the final release version is being prepared. This version supports target modules for the B-52, ALCM, C-130H, and C-17. Both the C-130H and C-17 codes have been provided to Georgia Tech Research Institute, at SPO request for use in defensive system simulations and evaluations. These models were developed and validated by the Airborne Measurements Branch from extensive measurements for this purpose by the FISTA.

Targets and backgrounds were measured during Joint Stars and C17 tests at Eglin AFB in Oct. 95. PL conducted ground to air measurements of the targets, flare releases, and backgrounds during low altitude passes of the E-8 Joint Stars aircraft and the C-17 aircraft. Instrumentation normally flown on the FISTA aircraft was operated from a small van specially outfitted for this test. Excellent data on target, flare, and background sources were measured and are available to support defensive system analyses for the Joint Stars program and the AMC.

The F-15E and F-16C models have been improved in the SPIRITS-AC2 Target Signature Model Update of F15 & F16 SPIRITS model from Version 4.25 to AC2: Significant new features and capabilities have been added to the SPIRITS target signature model since the development of the F-15E and F-16C aircraft modules. In order to allow these aircraft modules to be used with the updated software features, they have been updated and enhanced. New features include changing the nozzle geometry to match actual aircraft configuration at different power settings and more accurate engine hot gas and fan air mixing calculations for non-afterburner settings.

Measurement of C130H aircraft for AFSOC and AFIWC at Hurlburt Field, FL: In Feb. 96, PL/GPOA conducted ground to air measurements of C-130 aircraft. Measurements were conducted to determine signature comparisons between different types of C-130 aircraft with and without engine infrared suppressors.

As part of a significant instrumentation enhancement program for the FISTA aircraft, PL/GPOA developed the Multispectral Airborne Video Imaging System (MAVIS). The optical head is an intensified multiple spectral band video camera that uses a rotating, six position filter wheel to isolate spectral regions of interest. The current sensor provides response between 300 and 700 nanometers, and using changes in both detection time and image intensifier gain, a dynamic range of over 10^{10} is available. Absolute radiometric calibration of the system can be performed in the lab, while a portable, stabilized radiance source was developed to serve as an intermediate transfer standard for field calibrations.

CHANGES FROM LAST YEAR

The contrail forecasting program will be reduced due to funding limitations. A planned program to further evaluate a new GPS radio-occultation technique for global temperature and moisture profiling will be abandoned.

An optical turbulence measurement modeling effort has been initiated in order to meet the needs of next generation AF laser systems such as the ABL This program revives the earlier Geophysics of the 1980's which was tailored to ground based systems.

Based on the success of the C17 SPIRITS model, a major effort was begun to integrate the SPIRITS target signature predictions into broader aircraft/missile engagement models. With AFOTEC support, we will be enabling SPIRITS modules to be used with the imaging version of DISAMS (Digital Infrared Seeker and Missile Simulations). With this effort, existing validated SPIRITS models of aircraft like the B-52H, KC-10, C-130H, etc., can be used to define the target signature for missile engagements, that would also include high fidelity models of backgrounds, countermeasures (flares and jammers), and missile/seeker performance.

MILESTONES

Severe weather algorithms for, precipitation structures, tornadoes, hail, weather fronts, lightning, and other aviation weather hazards will go to the NEXRAD WSR-88D multi-agency Operational Support Facility (OSF) in FY97. Severe weather prediction software development will continue into FY99.

Demonstrate a theater-scale numerical weather model in FY97 which will include the effects of inferred cloud cover.

Evaluate the contrail forecast model in FY97 using data collected during the FY96 field program.

A capability to simulate high fidelity atmospheric phenomena including clouds, fog and rain will be developed by FY97.

Develop an algorithm to retrieve cloud vertical structure from microwave satellite data in FY97.

A capability to simulate 4-dimensional radiative weather scenes for IR sensors and night vision goggles (NVG) WIDAs will be developed in FY97. Development of global and theater weather analysis, simulation, and prediction techniques for combat weather system application will continue through FY02.

A theater-scale analysis procedure for EO WIDA support, combat weather displays and forecast model initialization will be completed in FY97. The development of the TFS technology will continue through FY97.

Techniques to identify hazardous electric fields in clouds for improved vehicle launch capabilities will be transitioned to AFSPC in FY98.

An analysis of cloud spatial structure and bidirectional reflectance distribution functions using very high resolution visible imagery will be completed in FY97.

A retrieval process for fused infrared and microwave data for atmospheric and surface parameters will be completed in FY98.

Diagnostic algorithms to satisfy TBM requirements for cloud, surface weather and aviation hazards will be transitioned to ESC/GTWAPS in FY98.

NOWS will transition to AFSOC and ACC in FY99.

Stoplight weather impact mission planning software will be transitioned to TBM system in FY01 as part of the Centralized Weather Support technology effort.

The development of techniques for producing synthetic atmospheres for hardware-in-the-loop simulations and other system design and engineering simulations, e.g., TACCSF, ABL, will continue through FY02.

New instrumentation for routine balloon-borne measurements of optical turbulence will be completed by FY97. These instruments will be used at various world wide locations in order to assist the development and improvement of turbulence and laser performance models through FY02.

Measurements of effluent plumes and chemical clouds by ground-based and airborne Lidar will continue through FY99. Development of IR and UV Lidar technology to meet these requirements will also continue.

The development and testing of eye-safe Lidars to meet AF remote sensing requirements, including ballistic winds, will continue through FY99.

The FISTA mission may be expanded to include airborne measurements and testing of an airborne qualified Lidar system. The Lidar installed onboard FISTA would support the FISTA electro-optical measurement capability by providing optical path characterization data from FISTA for both the foreground and background radiation. Lidar development is awaiting in-house or customer funding.

In FY97-98, the ability to integrate the SPIRITS target signature models into existing missile engagement models (DISAMS and MOSAIC) will be developed and demonstrated. This development will allow the large number of existing fighter, bomber, and transport aircraft target signature modules to be directly used by the missile engagement community. Also investigated will be the development of a JMASS compatible version of the SPIRITS target signature code to aid integration of SPIRITS into other higher level simulations.

GLOSSARY

50WS	50th Weather Squadron(formerly Air Force Space Forecast Center)
ABL	Airborne Laser
ACC	Air Combat Command
ADS	Atmospheric Density Satellite
AFEWES	Electronic Warfare Effectiveness Simulator
AFIWC	AF Information Warfare Center
AFMC	Air Force Materiel Command
AFOSR	Air Force Office of Scientific Research
AFSOC	Air Force Special Operations Command
AFSPC	Air Force Space Command
ALCM	Air Launched Cruise Missile
AMC	Air Mobility Command
ASC	Aeronautics Systems Center
ATD	Advanced Technology Demonstration
AWS	Air Weather Service
BMDO	Ballistic Missile Defense Organization
C3I	Command, Control, Communications and Intelligence
CBSD	Celestial Background Scene Descriptor
CCS	Charge Control System
CEASE	Compact Environmental Anomaly Sensor
CHAWS	Charge Hazards and Wake Studies
CIRRIS	Cryogenic InfraRed Radiance Instrumentation for Shuttle
CISM	Coupled Ionospheric Scintillation Model
CITFM	Coupled Ionosphere Thermosphere Forecast Model
CRADA	Cooperative Research and Development Agreements
CRES	Compact Radiation Effects Satellite
CRRES	Combined Release and Radiation Effects Satellite
DARPA	Defense Advanced Research Projects Agency
DIDM	Digital Ion Drift Meter
DISAMS	Digital Infrared Seeker and Missile Simulation
DMSO	Defense Modeling & Simulation Office
DMSP	Defense Meteorological Satellite Program
DNA	Defense Nuclear Agency
DOD	Department of Defense
DP	Development Prototype
DSCS	Defense Satellite Communication System
EO	electro-optical
ESC	Electronics Systems Center
EXCEDE	EXcitation by Electron DEposition
FASCODE	Fast Atmospheric Signature Code
FISTA	Flying Infrared Signatures Technology Aircraft
FLTSATCOM	Fleet Satellite Communications
FY	Fiscal Year
GP	Geophysics
GPS	Global Positioning System
HAARP	High Frequency Active Auroral Research Program
HF	High Frequency
IBSS	Infrared Background Signature Survey
IFM	Ionospheric Forecast Model
IMS	Ionospheric Measuring System
IR	Infrared
IRAD	Industrial Research and Development
ISEM	Integrated Space Environment Model

ISOON	Improved Solar Optical Observing Network
J-MASS	Joint Modeling and Simulation System
Lidar	Light Detection and Ranging
MAP	Mission Area Plan
MASC	Modeling and Simulation Center
MODTRAN	MODerate Resolution TRANsmission
MOSAIC	Modeling System for Advanced Investigation of Countermeasures
MOSART	Moderate Spectral Atmospheric Radiance and Transmittance
MSX	Mid-course Space eXperiment
NASA	National Aeronautical and Space Administration
NOAA	National Oceanic and Atmospheric Administration
NORAD	North America Air Defense Command
NOWS	Night Vision Goggle Operations Weather Software
NPOESS	National Polar Orbiting Environmental Satellite Sensors
OTH	Over the Horizon Backscatter Radars
PASP Plus	Photovoltaic Array Space Power Diagnostics
PE	Program Element
PL	Phillips Laboratory
PLEXUS	Phillips Laboratory EXpert Unified Simulator
PRISM	Parameterized Real Time Ionospheric Specification
RASWS	Remote Access Scintillation Warning System
RF	Radio Frequency
S&T	Science and Technology
SAMM	SHARC and MODTRAN Merged
SASS	Synthetic Atmospheric Structure
SBIR	Small Business Innovative Research
SBIRS	Space-Based InfraRed System
SFC	Space Forecast Center
SIG	SHARC Image Generator
SKIRT	Spacecraft Kinetic InfraRed Test
SMC	Space and Missile Systems Center
SPIRITS	Spectral In-band Radiance Images of Targets and Scenes
SPO	System Program Office
SPREE	Shuttle Potential and Return Electron Experiment
SSGM	Sybtgetuc Scene Generation Model
STIG	Space Technology Interagency Group
SWATH	Space Weather and Terrestrial Hazards
SWIPE	Space Waves in Plasmas Experiment
TA	Technology Area
TACCSF	Tactical Air Control Center Simulation Facility
TAP	Technology Area Plan
TBM	Theater Battle Management
TEC	Total Electron Content
TFS	Thermospheric Forecast System
TMD	Theater Missile Defense
TN	Technology Need
TPIPT	Technical Planning Integrated Product Team
USSOUTHCOM	US Southern Command
USSPACECOM	US Space Command
UV	Ultraviolet
WBMOD	Wide Band Scintillation Model
WIDA	Weather Impact Decision Aids
WSR-88D	Air Force Next Generation Doppler Weather Radar (Operational)

Technology Master Process Overview

Part of the Air Force Materiel Command's (AFMC) mission deals with maintaining technological superiority for the United States Air Force by:

- Discovering and developing leading edge technologies
- Transitioning mature technologies to system developers and maintainers
- Inserting fully developed technologies into our weapon systems and supporting infrastructure, and
- Transferring dual-use technologies to improve economic competitiveness

To ensure this mission is effectively accomplished in a disciplined, structured manner, AFMC has implemented the **Technology Master Process** (TMP). The TMP is AFMC's vehicle for planning and executing an end-to-end technology program on an annual basis.

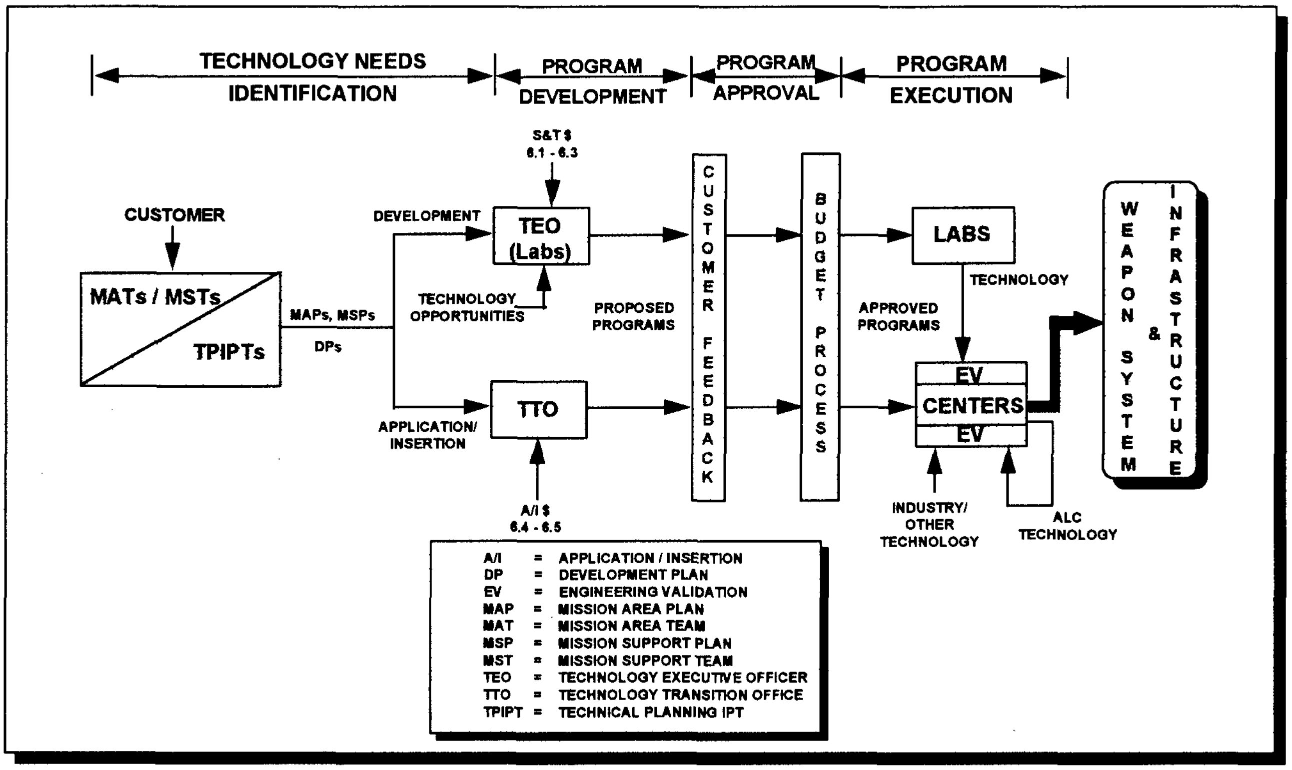

Figure 1 - Technology Master Process

The TMP has four distinct phases, as shown in Figure 1:

- Phase 1, **Technology Needs Identification** -- Collects customer-provided and customer-prioritized technology needs associated with both weapon systems, product groups and supporting infrastructure; then identify them by the need to develop new technology or apply/insert emerging or existing technology.

These needs are derived in a strategies-to-task framework via the user-driven Modernization Planning Process.

- Phase 2, **Program Development** -- Formulates a portfolio of dollar constrained projects to meet customer-identified needs from Phase 1. The Technology Executive Officer (TEO), with the laboratories, develops a set of projects for those needs requiring development of new technology, while the Technology Transition Office (TTO) orchestrates the development of a project portfolio for those needs which can be met by the application/insertion of emerging or existing technology.

- Phase 3, **Program Approval** -- Reviews the proposed project portfolio with the customer and obtains approval for the portfolio through the budgeting process. The output of Phase 3 is the authorizations and appropriations required, by the laboratories and application/insertion programs, to execute their technology projects

- Phase 4, **Program Execution** -- Executes the approved S&T program and technology application/insertion program within the constraints of the Congressional budget and budget direction from higher headquarters. The products of Phase 4 are validated technologies that satisfy customer weapon system and infrastructure deficiencies.

Additional Information

Additional information on the Technology Master Process is available from HQ AFMC/STR, DSN 787-6777/8764, (513)257-6777/8764.

INDEX