The Air Force Science & Technology Plan
Fiscal Year 2000

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Preface

A key component of the Air Force Vision (Global Engagement) and the new Air Force Strategic Plan is to pursue and take maximum advantage of technological advances so that we can retain our edge over potential opponents. The Air Force is therefore committed to a strong Science and Technology (S&T) Program. To better align our S&T Program with the Air Force Vision and Strategic Plan, and to reflect the recent organizational realignment of our multiple laboratories into the single Air Force Research Laboratory, we have consolidated our previous ten Technology Area Plans into a single, integrated Air Force S&T Plan. This document represents the first publication of that plan.

The objective of our S&T Program is to provide the technical foundation for the Air Force vision of Global Engagement. Our strategy is to make a balanced investment (far, mid and near-term) in a wide variety of militarily relevant technologies that will give us the edge against potential enemies in the twenty-first century.

Our situation is fundamentally different today than it was during the Cold War. We are less certain today who our future adversaries will be, what the nature or location of future conflicts will be, or what kinds of technologies will be employed against us. Advances in weapon-related technologies are proliferating at an alarming rate. Information and space technologies have become dramatic force multipliers, requiring additional focus on their use as well as defense against adversarial attack.

The S&T Plan must also be dynamic to serve these changing needs of our warfighters. This year, we have begun detailed planning for an Expeditionary Aerospace Force that calls for continued migration from an air force to a fully integrated aerospace force. Thus, we have adjusted and will continue to vector the S&T Program to include more emphasis on space as well as technologies that will enable lighter, leaner, and more lethal warfighting capabilities.

This Air Force S&T Plan provides a roadmap to our future. We hope this plan will be valuable to our DoD, Air Force, and other agency customers.

LAWRENCE J. DELANEY
Assistant Secretary of the Air Force for Acquisition

Foreword

Air Force Mission
To Defend the United States
Through Control and Exploitation of Air and Space

Air Force Science & Technology Mission
To Lead the Discovery, Development, Integration and Delivery of
Affordable Warfighting Technologies for Our Aerospace Forces

This science and technology (S&T) plan details the Air Force's S&T investment strategy for the Future Year Defense Plan (FYDP), which covers Fiscal Years 2000 to 2005. It is based on the DoD submission to the FY2000 President's Budget. While focusing on the FYDP, the Plan also presents the Air Force's vision of the technologies needed to support the warfighter in 2025.

The *Air Force S&T Plan* is organized into a main report and annexes. It is prepared biannually to coincide with "even" Program Objective Memorandum (POM) years, but may be updated for "odd" (adjusted POM) years if changes so warrant. This particular document represents the main report and is organized to reflect the three primary components of the Air Force Research Laboratory's (AFRL) S&T portfolio: Basic Research, Enabling Technologies, and Integrated Technology Thrust Programs (ITTPs). The ITTPs represent multidisciplinary, cross-directorate initiatives. The enabling technologies are organized by the nine technology disciplines represented by AFRL's nine technology directorates.

The annexes include (a) integrated technology roadmaps for our nine technology disciplines, and (b) FY2000 "new starts" (called Technology Investment Plans). The annexes contain top level funding data.

This *Air Force S&T Plan* replaces the former 10 technology area plans and provides an integrated picture of the Air Force's S&T investment for the future. This single plan correlates with the integration of our previous four laboratories into a single integrated organization – the Air Force Research Laboratory. AFRL has planning and execution responsibility for the Air Force S&T budget, as well as execution of significant reimbursable funds from other agencies.

RICHARD R. PAUL
Major General, USAF
Technology Executive Officer

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Executive Summary

The end of the Cold War and the emergence of new threats and challenges have brought about a dramatic transformation in the global security environment. To meet these challenges, the Air Force has established a new vision: *"Global Engagement: A Vision for the 21st Century."* This plan documents the U.S. Air Force's S&T investment strategy for FY2000-2005 to ensure that present and future warfighters have the best technologies to achieve that vision. This strategy is fiscally constrained, and is based on the FY2000 President's Budget submission.

The Air Force S&T investment strategy has three primary pillars. First, a portion of Air Force S&T investment will be shifted from aeronautical to space-related technologies between FY2000 and FY2005. This added emphasis on space is critical for enabling a truly integrated aerospace force for the future. Under this plan, Air Force technology funding for space will double from 13 percent of the FY1999 Air Force S&T budget to over 27 percent of the budget by FY2005. The source of these additional resources for space-related technologies will be a portion of our current aeronautical technology investment. Even when this shift is completed in FY2005, aeronautical technologies will still be the dominant component of the S&T portfolio. Second, Air Force S&T will pursue a set of focused programs across multiple technology disciplines to demonstrate new capabilities that support the warfighters' highest priority needs. These integrated technologies will directly enable the six core competencies in Global Engagement; will have a focused, specific nature, and will have products that are transitionable in three to six years. One-third of the Air Force S&T resources will be invested in these Integrated Technology Thrust Programs (ITTPs). Third, the Air Force will continue to pursue enabling technologies that are the "seed corn" for assuring future options for improved performance, sustainability and affordability, and thus serves as the foundation for the next generation of focused ITTPs.

The Air Force will maintain 50 percent of its S&T portfolio (as described above) in Defense Technology Objectives to ensure requisite technologies and advanced concepts for superior joint and coalition warfighting. Additionally, the Air Force S&T investment strategy will be to leverage external resources by jointly funding and coordinating programs with the other services, other government agencies, and with our university and industry partners. Finally, all technology programs will be examined from the perspective of enabling an Expeditionary Air Force by focusing both enabling technologies and ITTPs on lighter, leaner, and more lethal weapon systems.

To implement this strategy, the Air Force has consolidated its four laboratories into one – the Air Force Research Laboratory (AFRL). This consolidation enables integrated planning and execution of the Air Force S&T program that will lead to greater ability in meeting warfighter needs. Part of this consolidation was a major restructuring of the entire S&T portfolio into three elements: Integrated Technology Thrusts, Enabling Technology Areas, and Basic Research. This plan documents the Air Force investment strategy in each of these areas.

With the recent S&T reorganization, the Air Force has successfully embarked on the first leg of a journey to ensure it will continue to have the world's best aerospace technologies in the 21^{st} Century. This new integrated S&T structure fosters increased productivity within an environment of diminished resources. This plan will focus those resources on the Air Force's vision with an emphasis on results.

1.0 The Air Force S&T Organization

1.1 A Changing Air Force

The end of the Cold War, downsizing by the Department of Defense (DoD), and the emergence of new threats and challenges have transformed the global security environment. In the past, the United States faced a single, powerful adversary that put it at risk of nuclear attack with national survival at stake. This opponent was well understood and predictable. Now it faces three complex, unpredictable challenges: terrorism; rogue nations with weapons of mass destruction; and ethnic, religious and economic tensions undermining security in key strategic world areas. Whereas humanitarian support to countries such as Somalia and Bosnia were once infrequent missions, now these missions are becoming the norm. Today, U.S. troops are deployed to more places than they were 10 years ago but with a total force strength one-third smaller than at the end of the Cold War. This, coupled with the fact that first-world countries are no longer the only ones with access to technology information, creates a tremendous challenge for world security.

Clearly, the Air Force's approach to defending national security interests has changed tremendously over the last decade (Table 1-1). As the turn of the century approaches, declining budgets and world situations will continue to challenge Air Force capabilities.

Yesterday	Today
Known adversaries and understood threats	Unpredictable opponents, unknown challenges
National survival at stake	Vital interests at risk
Homeland at risk of Soviet nuclear attack	Homeland at high risk of limited terrorist attacks
Humanitarian and "lesser" operations a sideline	Multiple humanitarian and "lesser" operations the norm
Limited access to "leading-edge" technologies	Global technological proliferation
Slow spread of nuclear, biological and chemical (NBC) weapons	Rapid spread of NBC weapons
Expectation of prolonged conflicts, with large numbers of casualties	Expectation of decisive victories, with minimal casualties and minimal collateral damage
Extensive forward-basing structure	Project power increasingly from the U.S.
Information an adjunct to weapons	Information as a weapon / target

Table 1-1: The Changing Security Environment

1.2 Mission and Vision

The realization that traditional approaches and organizational structures will no longer be effective in resolving these challenges led the Air Force to establish a new vision: *Global Engagement: A Vision for the 21st Century*. This vision, based upon the DoD *Joint Vision 2010* of Full Spectrum Dominance, provides a conceptual template for how the Air Force should channel the vitality and innovation of its people while leveraging technological opportunities to achieve new levels of warfighting effectiveness.

AFRL Vision

- We defend America by unleashing the power of innovative aerospace technology
- Be the leader in aerospace technology
- Meet warfighter needs
- Pioneer new capabilities
- Assist and impact Air Force decision-making

This S&T Plan documents the Air Force strategy to help achieve the Global Engagement vision that ensures present and future warfighters will have the best technologies available.

To achieve this vision, the Air Force recognizes it must meet the warfighters' needs, both those perceived and those yet to be imagined. In today's world of technological proliferation, the way to maintain global dominance is to achieve new levels of effectiveness in joint warfighting. To do this, the Air Force must be the leader in aerospace technology by pioneering new capabilities and implementing them. The key to maintaining this technology leadership is a technically preeminent workforce. This workforce of innovators and visionaries will provide technical solutions to today's problems while defining what is possible for the future.

The Air Force mission requires complete success, second place is unacceptable. Thus, the bottomline mission of Air Force S&T is to provide the technology that will help keep the Air Force the best in the world. That's a tremendous challenge, but one which will be met by focusing on customer requirements. This plan is Air Force's S&T views for meeting those requirements. Essential to fulfilling this mission is discovering, developing and integrating technologies that meet the customer's requirements in the most cost-effective manner. This means not only implementing modern business management practices to improve efficiency and productivity, but also leveraging limited Air Force resources through a partnership with industry, other services, and other government agencies.

AFRL Mission

- To discover, develop, integrate and deliver affordable technologies for improved warfighting capabilities
- To lead a partnership of government, industry and university people
- To keep the Air Force the best in the world

1.3 AFRL

Faced with dramatic changes in mission and force structure, the Air Force consolidated its four laboratories and the Air Force Office of Scientific Research (AFOSR) into one laboratory–the Air Force Research Laboratory. Moving to a single laboratory allows the Air Force to preserve and enhance its ability to provide world-class aerospace technology in this dynamic new environment. AFRL remains a critical national asset, fully engaged in the vital work of scientific exploration, technological discovery, rapid transition of technology to the Air Force warfighter and the transfer of dual-use technology to the commercial sector.

AFRL is a full-spectrum laboratory responsible for planning and executing the Air Force's entire science and technology program. It is comprised of nine technology directorates and the AFOSR (Figure 1-1). Each technology directorate performs research and development (R&D) within their respective areas of responsibility. AFOSR manages, plans, coordinates and executes the AFRL's basic research program in response to technical guidance from AFRL and requirements of the Air Force. In addition, the technical directorates have a clear mandate to work with the other directorates in providing integrated technologies that satisfy customer requirements.

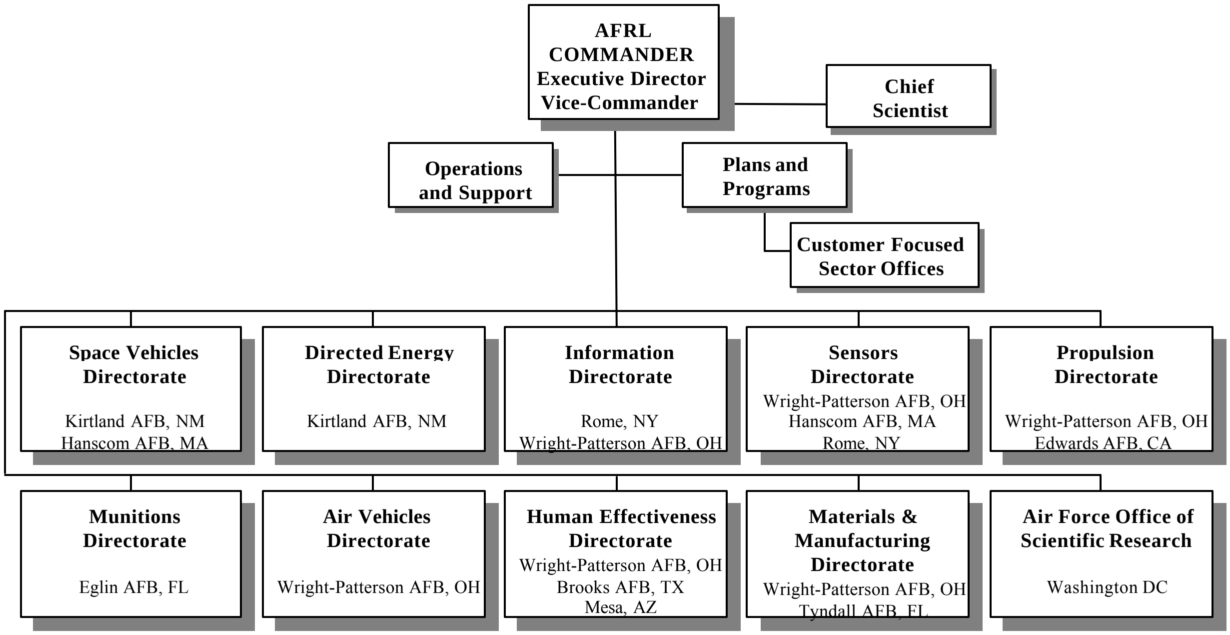


Figure 1-1: The AFRL Organization

A single Air Force Research Laboratory leads to
- Integrated technological solutions
- Greater agility in meeting warfighter requirements
- Improved accessibility for the customer
- Reduced overhead costs
- Optimal use of limited resources

Integrated planning and execution of the Air Force S&T program will lead to greater agility in meeting warfighter requirements along with an invigorated customer focused strategy for providing an immediate and sustained return on technology investments.

To help the directorates plan and integrate technology development, six sector offices have been formed within AFRL. These sector offices (Aeronautics, Space and Missiles, Command and Control, Human Systems and Logistics, Weapon Systems, and Modeling and Simulation) help formulate customer-focused strategies by providing a single point of entry for the customer.

2.0 The Planning Context

This S&T Plan supports the National Military Strategy: defend and protect U.S. national interests, promote peace and stability and when necessary, defeat adversaries.

The Joint Chiefs of Staff established *Joint Vision 2010* as an outline to achieve the National Military Strategy. It focuses on achieving dominance across a full spectrum of military operations through the application of new operational concepts. It also provides a template of common direction for the services in developing their unique capabilities within a joint framework of doctrine and programs. This vision of future warfighting embodies improved intelligence and command and control available in the information age and develops four operational concepts: Dominant Maneuver, Precision Engagement, Focused Logistics and Full-dimensional Protection. Each operational concept reinforces the others, allowing joint forces to achieve massed effects from dispersed forces. *Joint Vision 2010* will move DoD toward a common goal: a joint force that is persuasive in peace, decisive in war, and pre-eminent in any form of conflict. This vision forms the basis for Air Force strategic planning. Figure 2-1 depicts the flow down of strategic planning guidance to the Air Force S&T program and the resulting implementation strategy.

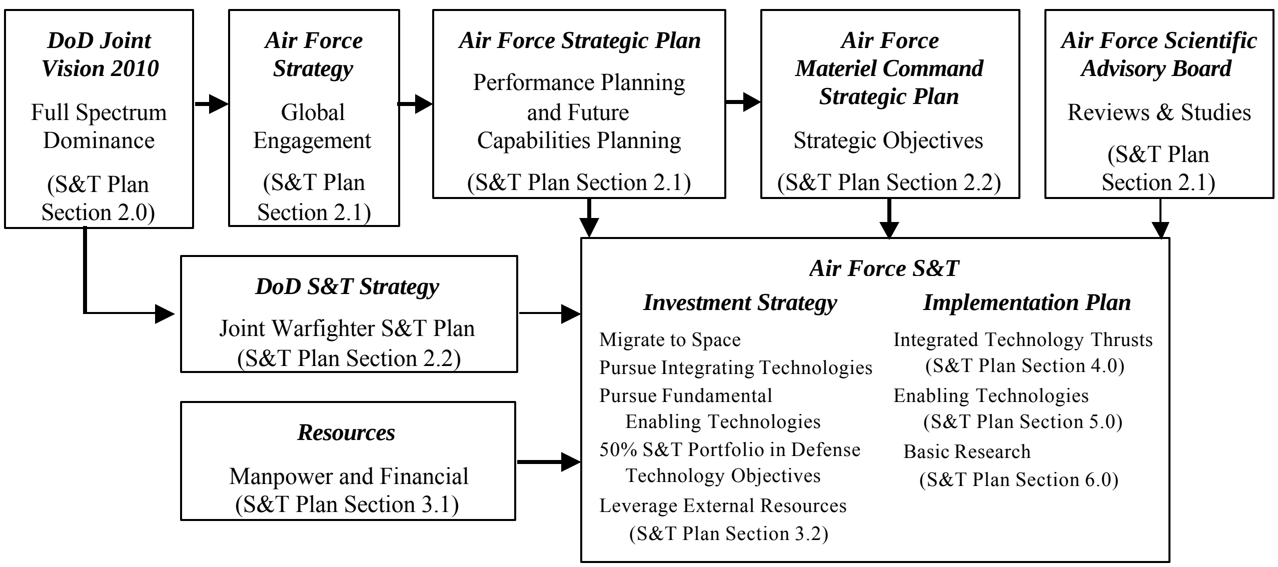


Figure 2-1: Air Force S&T Implementation of Strategic Planning Guidance

2.1 Air Force Strategic Planning

Air Force Core Competencies for *Global Engagement*

- Air and Space Superiority
- Global Attack
- Rapid Global Mobility
- Precision Engagement
- Information Superiority
- Agile Combat Support

From National Military Strategy and *Joint Vision 2010*, the Air Force has forged a new strategy that will lead it into the 21st Century: Global Engagement. This vision is based upon a new understanding of what air and space power means to the nation – the ability to directly hit an adversary's strategic centers as well as prevail on the operational and tactical levels of warfare. Global Engagement is the ability to orchestrate military operations throughout a theater of operations and bring intense firepower to bear over global distances within hours or days. Global situational awareness gives national leaders unprecedented leverage. To achieve the Global Engagement vision, the Air Force has identified six core competencies to focus on regarding the national defense and joint warfighter needs for the first quarter of the 21st Century.

The **first** core competency, Air and Space Superiority, assures a fundamental benefit to all forces across the spectrum of conflict, from peace to war. This superiority provides U.S. forces with dominant maneuver – the freedom to act and the freedom to attack.

The **second** core competency, Global Attack, has two dimensions. The first provides forces stationed in the United States with the capability of finding, fixing and attacking targets anywhere in the world within a matter of hours. The second dimension is expeditionary in nature and describes the ability to go forward and provide sustained combat power on foreign soil.

The **third** core competency, Rapid Global Mobility, is the key to going forward for all U.S. armed forces. It involves bringing forces forward for a full range of operations, from combat to peacekeeping to humanitarian efforts.

The **fourth** core competency, Precision Engagement, is the ability to precisely apply what is needed to influence events both on and off the battlefield. It involves delivering food, supplies and lethal ordnance, or attacking an adversary's command and control network.

The **fifth** core competency, Information Superiority, involves the ability to find, fix, or track and target, in near-real time, any object of significance, fixed or moving, on the surface of the Earth.

The **sixth** core competency is Agile Combat Support. It involves technologies that make forces light, agile and far ranging. This means not only lean logistics, but also rapidly deployable, light protection forces.

The Air Force Strategic Plan (AFSP) is designed to implement Global Engagement. The plan provides front-end guidance for modernization planning, provides the basis for accountability to implement the strategic vision, and outlines continuing activities and steps to tailor capabilities that meet *Joint Vision 2010.*

Complementing the Air Force vision and strategic plan, Air Force Materiel Command's (AFMC) Strategic Plan establishes the command's top priorities necessary to improve mission support from now to 2005. Their plan establishes five overarching specific objectives: Agile Combat Support, Weapon Systems, Cost, Work Force, and Infrastructure. The first three focus externally on customer issues, and the remaining two target central internal issues. As one of AFMC's eight business areas, Air Force S&T directly supports all five of these AFMC objectives.

AFMC Strategic Plan Objective Areas

- Agile Combat Support
- Weapon Systems
- Cost
- Work Force
- Infrastructure

In the area of Agile Combat Support, Air Force S&T is improving the Air Force's capability to rapidly and responsively deploy tailored forces supporting expeditionary force organizations. The Air Force S&T focus for Weapon Systems is to develop integrated products and processes to make sure future technologies for weapons systems are developed with built-in affordability and supportability. Initiatives in this area target the entire life cycle of the weapon system. The Air Force S&T goal for Cost is to identify and reduce support costs while maintaining technology quality. To do this, activity-based costing will be used to measure the total costs of doing business. Specific cost-reduction areas include manpower, non-research and development contracting, infrastructure and business practices. The Air Force S&T focus on the Work Force will be to evaluate the work force and ensure that it can meet the challenges of the Air Force's increased emphasis on space. The skill mix of both military and civilian employees will be assessed, and the full spectrum of government personnel options combined with contractor support will be used to meet the objectives. The S&T focus on Infrastructure will contribute to the development of more efficient, cost-effective technology. Additionally, innovative partnerships with local entities at the various research sites will enable more efficient operations.

Each of the aforementioned strategies, visions and plans, (the *National Military Strategy, Joint Vision 2010*, the *Air Force Strategic Plan* and the *AFMC Strategic Plan*) provides general guidance and priorities for this Air Force S&T Plan.

Air Force Scientific Advisory Board and National Research Council Studies

- New World Vistas
- Unmanned Air Vehicle Study
- Vision of Aerospace Command and Control for 21st Century
- Global Air Navigation
- Air Expeditionary Forces
- USAF Aging Aircraft
- A Space Roadmap for the 21st Century Aerospace Force

To identify specific technology needs and approaches within critical areas described in this plan, the Air Force sponsors the Scientific Advisory Board (SAB) and the National Research Council to conduct studies of specific Air Force interest. AFRL uses the recommendations from these studies to focus its S&T research. Several studies over the past three years have been completed. These include *New World Vistas (NWV), Unmanned Air Vehicle (UAV) Study, Vision of Aerospace Command & Control for the 21st Century, Global Air Navigation, USAF Aging Aircraft and A Space Roadmap for the 21st Century Aerospace Force.*

NWV – a 1995 study to identify key technologies that will have a profound impact on Air Force operations and systems into the first several decades of the 21st Century. In each area, technology opportunities were identified for development within 20 years and beyond 20 years. This study provides the primary focus for AFRL's basic research investment strategy.

UAV Study – a 1996 study sponsored by the Chief of Staff of the Air Force (CSAF) to review technology maturity in the context of accepted Air Force mission tasks and to project new UAV combat and noncombat mission tasks which might be enabled by available and forecasted technologies. This study provides guidance to AFRL's ITT on Precision Strike.

Vision of Aerospace Command and Control for the 21st Century – a 1996 study sponsored by the CSAF to establish a vision of aerospace command and control for the 21st Century. This study identified specific technology areas to pursue for future command and control. In response to this study, AFRL has incorporated the results into the ITT on Information Dominance.

Global Air Navigation – a 1997 study that examined the changes necessary in Air Force equipment and procedures to respond to changes in global civilian airspace architecture. Results of the study have been factored into planning for AFRL's ITT on Information Dominance.

Air Expeditionary Forces – a 1997 study jointly sponsored by the Secretary of the Air Force (SAF) and CSAF to identify operational concepts and new systems and technologies required to develop an enhanced Air Force capability for expeditionary operations. Initial steps have been taken to respond to these needs with specific programs included within the ITT on Agile Combat Support.

U.S. Air Force Aging Aircraft – a 1998 study by the National Materials Advisory Board of the National Research Council and sponsored by the AFOSR. The report highlights findings that could threaten aircraft safety, become an excessive economic burden, adversely affect force readiness, or which would make the maintenance burden so high it would no longer be viable to retain the aircraft in inventory. In response to this report, AFRL formed and led a joint Air Force, NASA, and Federal Aviation Administration (FAA) team to develop a *Joint Aging Aircraft Plan*. The results of this plan are incorporated within the AFRL Aircraft Sustainment ITT.

A Space Roadmap for the 21st Century Aerospace Force – a 1998 study jointly sponsored by the SAF and CSAF to identify operational concepts, new systems and technologies needed to develop an enhanced Air Force space capability. AFRL will review this report when it is released to determine the impacts to AFRL space activities.

2.2 DoD S&T Strategic Planning and Oversight

The Director of Defense Research and Engineering (DDR&E) through the Deputy Under Secretary of Defense for Science and Technology, DUSD(ST), is responsible for the direction, quality and content of the DoD S&T program under the Defense S&T Reliance Process. DUSD(ST) chairs a Defense S&T Advisory Group (DSTAG) to ensure the program responds to the needs of the U.S. national goals and in particular, the

U.S. military. DDR&E documents the DoD S&T program in a series of three plans: the *Defense Technology Area Plan*, the *Basic Research Plan*, and the *Joint Warfighting S&T Plan.*

The *Defense Technology Area Plan* (DTAP) presents DoD objectives and applied research and advanced technology development investment strategies for technologies critical to DoD acquisition plans, service warfighter capabilities and the Joint Warfighting S&T Plan. There are 12 DTAP panels comprised of expert teams of senior service and agency personnel who focus S&T investment through Defense Technology Objectives (DTOs). Figure 2-2 shows AFRL Technical Directorates' participation in DTAP panels.

Enabling Technology Areas \ Defense S&T Panels	Space Platforms	Information System Technology	Sensors, Electronics & EW	Weapons	Air Platforms	Human Systems	Materials/ Processes	Biomedical	Ground And Sea Vehicles	Chemical/ Biological/ Nuclear Defense	Nuclear Technology	Battlespace Environment
Space Vehicles	●		○									○
Directed Energy	○	○	○	○						○		○
Information		○	○									○
Sensors			○	○								○
Munitions				●								
Propulsion	○			○	○							
Air Vehicles					●	○						
Human Effectiveness						○	○	●				
Materials & Manufacturing							○					

● = Lead ○ = Participating

Figure 2-2: DTAP Panels Participation by AFRL Technical Directorates

The *Basic Research Plan* (BRP) presents objectives and investment strategy for DoD-sponsored basic research performed by universities, industry and service laboratories. This plan presents the planned investment for each of the 12 basic research areas and details the six strategic research objectives.

The *Joint Warfighting S&T Plan* (JWSTP) also takes a horizontal perspective of the exploratory development and advanced technology development plans, but for a different purpose. Its objective is to ensure that the S&T program supports priority future joint warfighting capabilities. The JWSTP identifies capability objectives for tri-service.

Together these three plans ensure that the near-, mid-, and far-term joint warfighter needs are properly balanced and supported in S&T planning, programming, budgeting and assessment activities. In both the DTAP and JWSTP, the S&T investment is focused and guided through DTOs. Each DTO identifies a specific technology that will be developed and demonstrated, its availability date, specific benefits resulting from the technology, and the funding required to achieve the new capability. To assess compliance with program guidance, DDR&E Technology Area Review and Assessment (TARA) teams, comprised primarily of outside technology experts, review the DTAPs.

Joint Warfighter Capability Objectives

- Information Superiority
- Precision Force
- Combat Identification
- Joint Theater Missile Defense
- Military Operations in Urban Terrain
- Force Projection/Dominant Maneuver
- Electronic Combat
- Combating Terrorism
- Chem/Bio Warfare Defense & Protection & Counter WMD
- Joint Readiness & Logistics & Sustainment of Strategic Systems
- Protection of Space Assets

2.3 Air Force S&T Planning Process

This S&T plan documents the science and technology investments needed to achieve the Air Force's Global Engagement vision and support the Air Force Strategic Plan. The process to establish, approve and execute this plan is shown in Figure 2-3. This figure depicts how the Air Force S&T plan is responsive to guidance at both the DoD and Air Force levels. DoD includes operational guidance from *Joint Vision 2010* and the *Defense Planning Guide* (DPG). The DoD Deputy Director for Research and Engineering (DDR&E) provides S&T guidance through the *Basic Research Plan* (BRP), *Defense Technology Area Plan* (DTAP) and Joint *Warfighter S&T Plan* (JWSTP). The primary Air Force planning Documents for guidance to the Air Force S&T Plan are the Air Force's *Annual Planning and Program Guidance* (APPG), the Air Force Strategic Plan (AFSP) and the *Air Force's Modernization Planning Process* (AFMPP).

Based on the planning priorities and resources allocated from DoD and Air Force guidance, AFRL executes the Air Force's S&T Planning, Programming and Budget Process (PPB). Throughout the PPB process, AFRL conducts programmatic reviews with the Air Force's Scientific Advisory Board (SAB), the Air Force's Major Commands (MAJCOMs) and other DoD agencies through the Joint Directors of Laboratory's Technology Area Review and Assessments (TARAs). Based on DoD and Air Force guidance and external reviews, AFRL develops a Program Objective Memorandum (POM) which forms the baseline for the Budget Estimate Submission (BES) on Air Force S&T. Following congressional mark-up and approval of the President's budget, AFRL executes the Air Force S&T Plan. The execution of the S&T plan is detailed in Annex A.

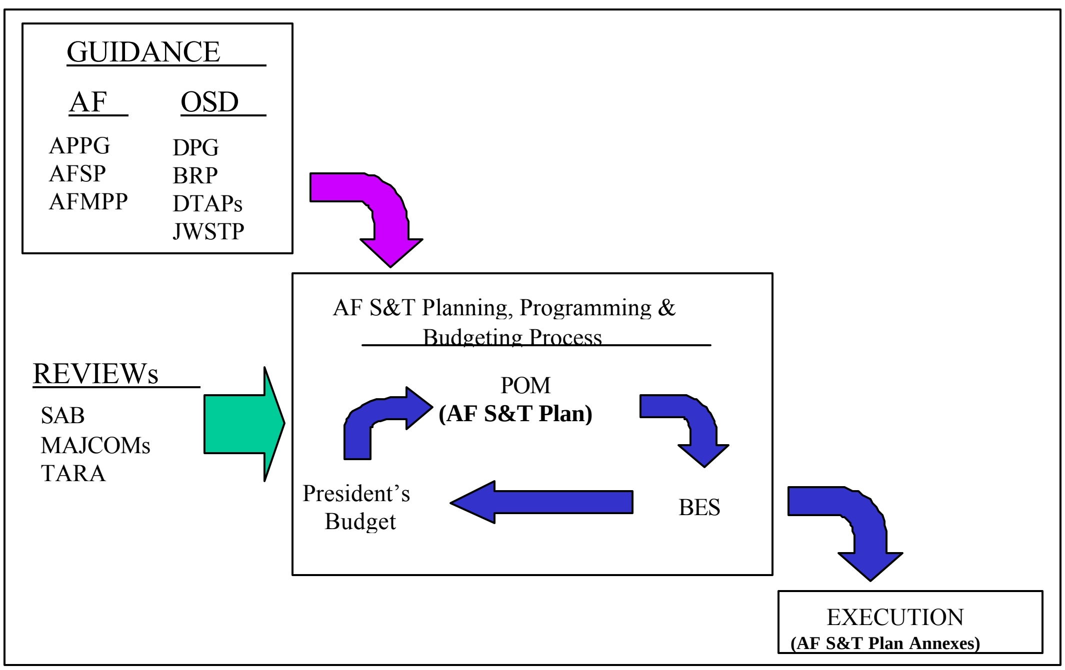


Figure 2-3: AFRL Planning, Programming and Budgeting Process

3.0 The Air Force S&T Resources and Investment Strategy

3.1 Air Force S&T Resources

Air Force S&T resources are derived from a section of the federal budget called Major Force Program 6. Of this program, AFRL manages Basic Research (6.1) and Exploratory Development (6.2). These form the Air Force's technology base. Advanced Technology Development (6.3) demonstrates technology maturity before transitioning to specific system applications (Figure 3-1).

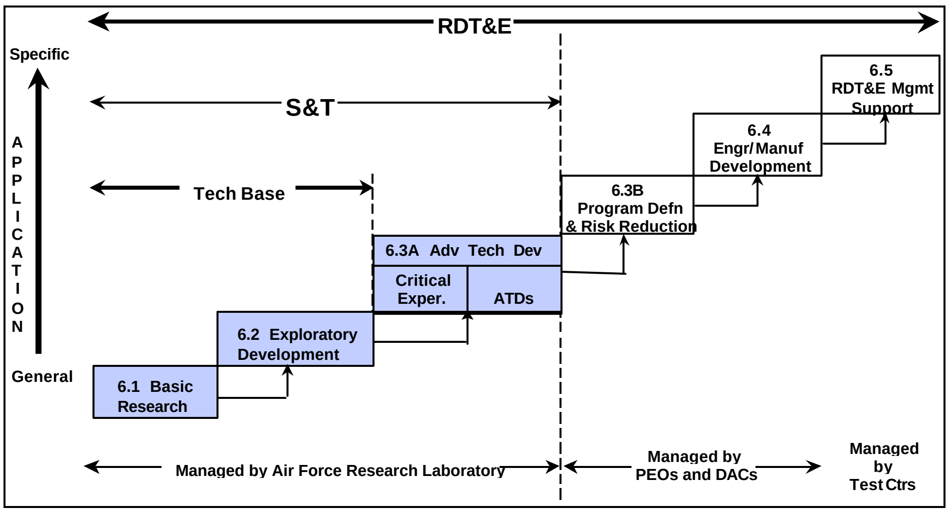


Figure 3-1: Major Force Program 6 Relationship (3600 Appropriation)

The Air Force uses these resources to develop technologies across the spectrum from the near-term to the far-term (Figure 3-2). Over the FYDP, AFRL estimates that approximately one third of Air Force S&T funding will be in near-term advanced development (6.3). These activities are primarily focused at the sub-system level, essentially increasing service life and enhancing current capabilities. Approximately one-half will be in exploratory development activities (6.2) providing evolutionary technologies for more affordable and capable solutions for today's systems. The remainder of Air Force S&T funding will be in far-term basic research (6.1) for developing revolutionary technologies that affect how the Air Force conducts warfare in the far-term, although some mid-term payoff at the system level is possible. AFRL employs more than 6,000 people and invests around $1.2 billion annually, about 2 percent of the Air Force Budget. Of this, 80 percent is invested with

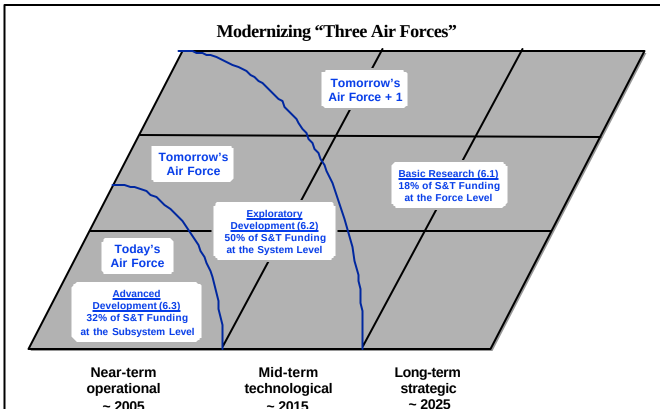


Figure 3-2: AFRL is Developing the Technologies to Modernize the "Three Air Forces"

universities and industry. Figure 3-3 is a summary of Air Force S&T funding (not adjusted for inflation which shows the FY2000 President's Budget (PB remains essentially unchanged from the FY99PB).

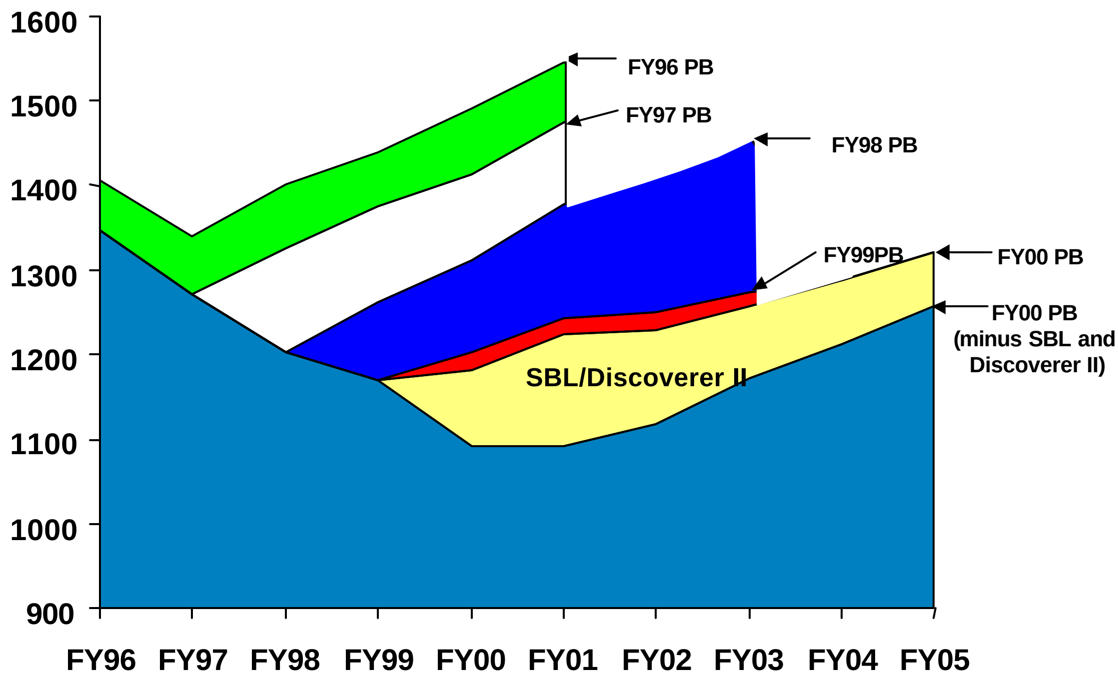


Figure 3-3: Air Force S&T Budget History (FY $M)

3.2 The Air Force S&T Investment Strategy

> **Air Force S&T Investment Strategy**
> - Migrate investment from aeronautical to space
> - Pursue integrated technology solutions to support warfighters' highest priority needs
> - Pursue fundamental enabling technologies that improve tomorrow's Air Force
> - Maintain 50 percent of Air Force S&T Portfolio in Defense Technology Objectives
> - Leverage external resources

The Air Force S&T Investment Strategy reflects the priorities identified in Section 2.0 and the projected S&T resources identified in Section 3.1. This investment strategy sets the framework for more detailed S&T planning. First and foremost, the strategy calls for migration of investment from aeronautical to space-related technologies to enable the aerospace force of the future. This will be done by increasing the space investment, maintaining the air and space investment, and protecting and focusing on the most critical air investment. An essential portion of the Air Force S&T investment strategy is to pursue integrated technology thrust programs across technology areas to support the warfighters' highest priority needs. All this work is supported by fundamental enabling technologies that provide options for improved performance, sustainability, and affordability in tomorrow's Air Force. Finally, AFRL intends to maintain 50 percent of the Air Force S&T portfolio in DTOs and to leverage external resources by jointly funding and coordinating programs.

3.2.1 Migrate More Investment From Aeronautical To Space-Related Technologies

Migration to Space

- Increase the space investment
- Maintain investment applicable to both air and space
- Focus aircraft only technology to most critical elements

The motivation for more focus on space-related technologies comes from several sources. The Global Engagement vision calls for migration from an air and space force to a space and air force. An Air Force Corona briefing (Feb 98) urges a reapportion of S&T Funding to space. A *Doable Space Study* calls for expanding and focusing space R&D (including S&T) and SAF/AQ encourages an increase in the space portion of the AFRL FY00 POM.

This emphasis on space is critical to enable the aerospace force of the future and builds a new foundation for Air Force space operations early in the 21st Century. Under this plan, Air Force technology funding for space will double by 2005. However, because of zero real growth in the S&T top-line, some of the investment shift for space will come from aircraft specific technologies. To mitigate the impact to aircraft specific technologies the Air Force will aggressively leverage external opportunities towards space. Two examples of this leveraging, which are new programs beginning in FY00, are outlined below.

Discoverer II is a collaboration with the Defense Advanced Research Projects Agency (DARPA) and the National Reconnaissance Office (NRO). Discoverer II will demonstrate the technical feasibility and cost affordability of a space-based system offering high-range-resolution ground moving target indication (HRR-GMTI), synthetic aperture radar (SAR) imaging, and high-resolution digital terrain mapping data collection capabilities that will be directly taskable by theater or joint task force commanders and that will directly downlink collected data to theater ground stations. The Discoverer II program will design, fabricate and launch two research and development prototype HRR-GMTI/SAR satellites, and conduct a one-year, on-orbit demonstration with the satellites in Fiscal Year 2004.

Space Based Laser Integrated Flight Experiment (SBL IFX) is a joint program with the Ballistic Missile Defense Office (BMDO). SBL IFX is scheduled to be launched in the 2010-2012 timeframe and will demonstrate the integration of all components into a space weight platform that will perform a series of on-orbit experiments and demonstrate boost phase intercept feasibility.

Despite the leveraging of external opportunities the implementation of the strategy to place more emphasis on space technologies means some non-space areas will be maintained or decreased while others will be eliminated. Air and space technologies, such as space unique electronics and space vehicle materials, are maintained. Many conventional air investments, such as performance technologies for fighters and conventional turbine engine technologies, are eliminated or reduced. Remaining investments will be focused on critical areas, such as aging aircraft.

3.2.2 Pursue ITTs That Support Warfighters' Highest Priority Needs

In line with the Global Engagement vision, the Air Force has fundamentally restructured its entire S&T portfolio. Six ITTs form the centerpiece of this restructuring effort (Space Superiority, Precision Strike, Information Dominance, Aircraft Sustainment, Agile Combat Support and Training for Warfighting).

These ITTs represent the application of enabling technology research projects and integrate technology opportunities across the laboratory. They capture over a third of the resources in the FY00 POM and further align efforts to the AFSP. The ITTs provide the roadmap for pioneering new warfighting capabilities for the Aerospace Force of the 21st Century. The programs under each ITT are multidisciplinary, spanning across technology areas that address a major customer need; have a focused, specific nature; have products transitionable in three-to-six years; and are managed by an AFRL program manager residing in a lead technology directorate. To have a focused, specific nature, the ITT program must have a defined roadmap that includes a funding profile and a development schedule with milestones leading to a transitionable product. Detailed explanations of the ITTs are presented in Section 4.0.

Modeling and Simulation (M&S) tools are essential for developing better, faster and cheaper air and space power; therefore, a new initiative in M&S is underway in FY00. This initiative is to enhance M&S capabilities across the technology directorates by collaborating in common areas. New M&S tools will be developed via three initiatives: Collaborative Environment Technology, Cognitive Process Modeling, and Model Abstraction. Collaborative Environment Technology includes advanced distributed modeling tools and an open system framework for the integration of technologies. Cognitive Process Modeling covers integration of artificial intelligence techniques with stochastic modeling techniques for modeling behavior. Model Abstraction includes the use of abstraction techniques (fuzzy simulation, dependency determination), mixed resolution simulation and component coupling approaches.

3.2.3 Pursue Fundamental Enabling Technologies

Enabling technologies are emerging technologies that address broad modernization requirements. These technologies are the “seed corn” for assuring future technology superiority and serve as the foundation for the next generation ITT programs. The Air Force S&T strategy maintains a significant part of the investment to support enabling technologies and the associated basic research. Basic research can be defined as “blue sky” research which is synonymous with unorthodox or “outside the box” research. It could result in revolutionary breakthroughs and quantum leaps essential to meeting projected far-term challenges and opportunities.

3.2.4 Maintain 50 Percent S&T Portfolio Balance in DTOs

The Defense S&T Panel has identified 352 DTOs and the Air Force participates in 138 of these. AFRL has established a centralized AFTO selection process for DTO candidates to achieve more balanced Air Force participation across the Defense Technology Areas. Each ETA made adjustments in their DTO participation to achieve the AFRL approved position of 50 percent of the S&T portfolio investment in DTOs.

The AFTO process will corporately develop and identify high priority Air Force S&T programs that require the commitment of investment involved with the DTO process. The AFTO process allows AFRL/CC, the AFRL Corporate Board, and SAF/AQ to review and approve AFTO candidates prior to their official submission as candidate DTOs. These candidates must be based on either ITT programs or Enabling Technology Area (ETA) programs; must address desired future capabilities identified in the AFSP or Modernization Planning Process (MPP) deficiencies; must demonstrate customer concurrence that the specific technology being developed will increase a needed military operational capability; and must be fully funded, have definite start and end dates, and an anticipated date of technology availability.

3.2.5 Leverage External Resources by Jointly Funding and Coordinating Programs

Air Force S&T has three basic operating tenets: to outsource a majority of the S&T budget to industry/academia; to pursue small, focused in-house programs; and to aggressively leverage other government agencies, private sector, and international investments. The methods of leveraging resources within the S&T community vary from one activity to another. The primary Air Force S&T partners are DARPA, industry, NASA, academia, the Air Force Battle Labs, other military services, the MAJCOMs and the AFMC Product Centers. Figure 3-4 shows the relationship of internal to external resources managed by the Air Force S&T organization.

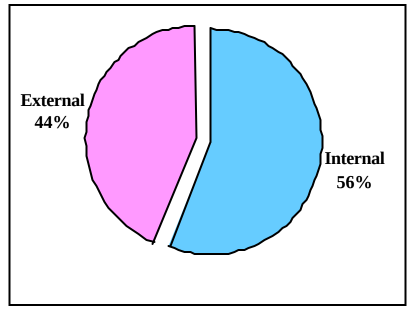


Figure 3-4: Relationship of Internal to External Resources

In addition to leveraging external resources, the Air Force leverages commercial technology developments through Cooperative Research and Development Agreements (CRDAs), Small Business Innovation Research (SBIR), and Dual Use Science and Technology (DUS&T).

Cooperative Research and Development Agreements

The Air Force has partnered with companies and individuals, through CRDAs, to take advantage of the aspects of the technology development that apply to military requirements.

Small Business Innovative Research

The SBIR program is a congressionally mandated program encouraging all federal science and engineering activities to share their technologies and developments with the public and private sectors. The primary or intended purpose is to commercialize the technology in an effort to increase the socio-economic well being of the United States. The SBIR program’s budget for the last two years has been over $200 million. AFRL is enhancing SBIR planning at the ETA level. The technology directorates have aligned their SBIR topics with their strategic S&T planning objectives in order to improve the consistency between their normally contracted and intramural projects with the SBIR topics.

Dual Use Science and Technology

The congressionally mandated Air Force DUS&T Program jointly funds the development of technology providing both militarily relevant and commercially viable products. The intent of the Air Force DUS&T is to leverage industry's internal technology development activities and investments. This provides technology development projects that are inherently different from conventional Air Force technology development efforts. Overall this program focuses on leveraging the resources and interests of industry and primary Air Force S&T partners.

4.0 Integrated Technology Thrusts

To better respond to the needs of the Air Force and DoD, the AFRL has integrated its major technology programs across directorates in the form of Integrated Technology Thrusts (ITTs). The ITTs are groupings of related, high visibility programs that support the warfighters highest priority needs. They align with the Air Force S&T Strategic Emphasis Areas and include Integrated Aerospace Force, Precision Engagement, and Aircraft Sustainment and Expeditionary Aerospace Force (EAF).

Each ITT is comprised of several Integrated Technology Thrust programs (ITTPs). ITTPs are multi-disciplined, integrated technology efforts designed to address key Air Force near-term to mid-term needs. To become an ITTP, the program must meet strict criteria. The program must support a documented critical warfighter high priority operational need as identified through the AFMPP and it must align with Air Force core competencies. The program must have a specifically focused objective based upon an operational need. The specific technology deliverable must be identified, and the timeline and budget to achieve the required capability must be well defined. To ensure all critical technologies to achieve the desired operational capability are addressed, the program must have an established cross-directorate baseline with support of a cross-directorate integrated team. This team will identify all critical technologies and develop a roadmap with critical milestones to be met. Since the purpose of the ITTPs is to meet identified near-term to mid-term customer needs, they must provide a transitionable product to that customer within three-to-six years.

Criteria Required to Form an ITTP

- Be aligned with Air Force core competencies through the ITTs, or meet critical Air Force operational needs
- Have a focused specific objective, with a defined budget, timeline, and technology deliverables
- Have an established cross-directorate baseline, managed by the ITTP manager with support of a cross directorate integrated team
- Provide transitionable products in three to six years

The AFRL S&T ITTs and the first set of associated ITTPs are identified in Table 4-1. These ITTs are built on the technology foundation represented by the Air Force's critical enabling technology base (core technology), and basic research investment and will, where necessary, be demonstrated through Advanced Technology Demonstrations (ATDs).

AFRL ITTs	AFRL ITTPs	
Space Superiority (Section 4.1)	• Space Operations Vehicle (SOV) • Space System Survivability • Hyperspectral Imaging	• Space Based Radar (SBR) • Space Optics & Laser Technology
Precision Strike (Section 4.2)	• Small Smart Bombs (SSB) • Automatic Target Recognition (ATR) • Unmanned Combat Air Vehicles (UCAV) • Real Time Sensor-to-Shooter Operations	• Low Cost Autonomous Attack Systems (LOCAAS) • Electro-Optical Countermeasure/Infrared Countermeasure (EOCM/IRCM) • Sensor Protection
Information Dominance (Section 4.3)	• Configurable Aerospace Command and Control • Defensive Information Warfare • Dynamic Command & Control	• Consistent Battlespace Picture • Global Grid
Aircraft Sustainment (Section 4.4)	• Aging Aircraft Structures • Low Observable (LO) Maintainability	• High Cycle Fatigue (HCF) • Turbine Engine Durability
Agile Combat Support (Section 4.5)	• Deployment Planning, Command and Control Reduced Airlift & Sustainment • Deployed Base Support Systems	• Force Protection • Active Denial Technology (ADT)
Training for Warfighting (Section 4.6)	• Simulation & Distributed Mission Training	• Warfighting Operations Center Training

Table 4-1: AFRL's ITTPs

AFRL sector offices will lead the development of ITTs and will lead cross-directorate teams to mature individual ITTs, consistent with AFRL strategy. Each ITT will be assigned to an AFRL lead directorate for successful execution. The Air Force's ITTs and their correlation to AFRL technology directorates and AFOSR is presented in Figure 4-1. Specific details on the technical scope, direction, timetable and funding for the ITTs and ETAs are in Annexes A & B, respectively.

Integrated Technology Thrusts / AFRL Technology Directorates	Space Superiority	Information Dominance	Precision Strike	Aircraft Sustainment	Agile Combat Support	Training for Warfighting
Space Vehicles	●	●	●			●
Directed Energy	●		●		●	
Information	●	●	●		●	●
Sensors	●	●	●		●	
Munitions			●			
Propulsion	●		●	●	●	
Air Vehicles	●		●	●	●	●
Human Effectiveness		●	●		●	●
Materials & Manufacturing	●		●	●	●	
Air Force Office of Scientific Research (AFOSR)	●	●	●	●	●	●

Figure 4-1: Technology Directorate and AFOSR participation in ITTs

4.1 Space Superiority

"Operate with Impunity in and through Space"

Space operations have become an integral part of U.S. military strategy. Desert Storm clearly demonstrated this fact. Space assets were a major factor in achieving military dominance. In the future, space assets will be increasingly relied on to ensure air and space supremacy. Global Engagement calls for a migration from an air force to a space and air force, and the Air Force is committed to this goal. The Space Superiority ITT will make this possible by focusing Air Force technologies on the space environment to ensure continued space superiority in the next century.

4.1.1 Space Superiority ITT Planning Context

The Air Force's vision is to fully integrate air and space forces. This vision was forged from the Joint Chiefs of Staff *Joint Vision 2010*, which focuses on achieving dominance across a full spectrum of military operations through the application of new operational concepts. To achieve this dominance, the Air Force has identified six Global Engagement core competencies. Space systems will play a vital role in five of these six core competencies: Air and Space Superiority, Information Superiority, Precision Engagement, Global Attack and Rapid Global Mobility. To realize these core competencies, the Air Force has designed a strategic plan which recognizes that military use of space will grow. It further recognizes that adversaries and allies alike will have access to space-based systems or their products, and that space will increasingly become the essential high ground. Because of this, space superiority is essential to U.S. military strength.

To support *Joint Vision 2010*, the Air Force's vision of Global Engagement and the *Air Force Strategic Plan*, the Air Force Space Command (AFSPC) has identified several deficiencies, needs and capabilities in their Mission Area Plans (MAPs) and Strategic Master Plan (SMP). In the near-term, improved threat warning/attack reporting and space-based all weather surveillance is needed. In the mid-term, the ability to track and characterize targets from space and to image any location on earth at any time will be required. In the far-term, cost effective, rapid access to space; protection of space assets from hostile environments and threats; long-range, speed of light engagement from space; and detection of nuclear, biological and chemical (NBC) agents from space are desired.

In addition to the above, recommendations and findings from several studies such as *New World Vistas*, *Spacecast 2020*, and *Doable Space* have supported the development of this ITT strategy. The SAB has recently completed a new study titled *A Space Roadmap for the 21st Century Aerospace Force*. These studies, in context with the previously discussed visions and plans are being used to focus the Space Superiority investment strategy.

4.1.2 Space Superiority ITT Investment Strategy

Space Superiority ITTPs

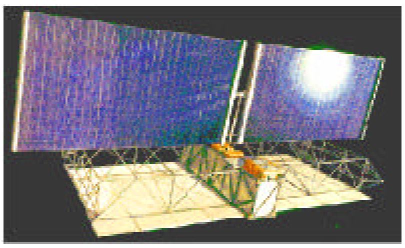
- Space-Based Radar
- Space Operations Vehicle
- Hyperspectral Imaging
- Space System Survivability
- Space Optics and Laser Technology

The Space Superiority ITT is supporting Global Engagement, the associated Air Force Global Engagement core competencies and an integrated aerospace force by significantly increasing the space-unique portion of the Air Force's S&T investments and by enhancing integration of its planning process with key space customers and partners. The Space Superiority ITT's investment strategy is to support AFSPC high priority efforts such as Space-Based Radar (SBR), Space Optics and Laser Technology, Space Operations Vehicle (SOV), Hyperspectral Imaging and Space System Survivability. To formulate the technical strategy that supports these high priority efforts, this ITT works closely with AFRL's space technology customers. This includes providing support to the MAP process. This enables AFRL to identify technology needs for current deficiencies and to better help users focus the bounds of what is possible for the future, and in what time frame.

This ITT's investment strategy focuses on a wide range of space efforts, from providing access to space, surveillance, target identification, and threat detection and protection, to lethal engagement. The programs that constitute the Space Superiority ITTPs are SBR, SOV, Hyperspectral Imaging, Space System Survivability and Space Optics and Laser Technology. For each of these ITTPs, technical objectives have been established. These objectives and a brief explanation of each ITTP are provided.

Space-Based Radar

Objective: Detect and track targets of military interest in the theater of operations and around the world

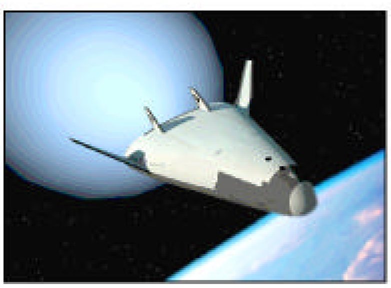


Radar for World-Wide Surveillance

This program develops the technologies to field a SBR system capable of doing ground moving target indication, air moving target indication and battlefield imaging. Missions include near-real-time support to any theater, worldwide, and a CONUS defense role requiring wide area surveillance of oceans and landmasses. Technology areas support monostatic, bistatic and distributed satellite concepts developed under the Air Force Modernization Planning Process.

Space Operations Vehicle

Objective: Assure cost-effective and rapid access to space



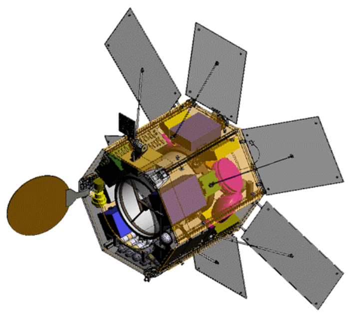
Reusable Launch Vehicle

The SOV program enables revolutionary improvements in space access and operations while dramatically lowering the cost of launches. The SOV system has three components: a rocket-powered, suborbital, reusable booster; the Space Maneuver Vehicle (SMV)–a reusable spacecraft bus; and a low-cost, expendable Modular Insertion Stage (MIS) for boosting 2,000-4,000 pound tactical satellites into low-earth orbit. The SOV system will enable AFSPC and the Commander-in-Chiefs to achieve aircraft-like operability for space access. The operational system will have turn-around times measured in hours, multiple sorties per week, easy maintenance, and a long life. This capability will offer an order of magnitude decrease in the cost of access to space while dramatically increasing operational flexibility and overall capacity.

Congress gave NASA the lead in the development of Reusable Launch Vehicles (RLVs). AFRL is working in close coordination with NASA to develop technologies for unique military needs while remaining compatible with NASA's RLV. This teaming arrangement allows AFRL to maximize the return on investment for the Air Force and significantly reduce costs.

Hyperspectral Imaging

Objective: Provide a superior capability for 21st Century aerospace surveillance and intelligence needs



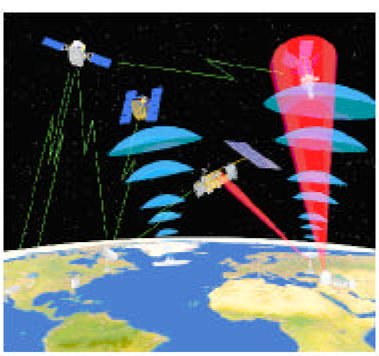
Space and Air Surveillance System

The charter of this program is to lead a coordinated, AFRL-wide effort to assess the potential military utility of hyperspectral technologies for the Air Force within the context of MAJCOM concepts, deficiencies and technology needs. The Hyperspectral Imagery ITTP is overseeing the development of key technologies to provide the Air Force with a superior capability to meet 21st Century space-based and aircraft-based surveillance and intelligence needs. In the future, space-based assets will provide wide-area coverage, access to denied areas, and near-instantaneous coverage of regions of interest. These assets will also be employed to manage airborne assets for close-up, detailed coverage, as operations require.

Payoffs to the Joint Task Force commander will include Intelligence Preparation of the Battlefield (IPB) (Fixed and Mobile Surface Target Detection and Identification, Terrain Classification, Trafficability and Lines of Communication), Aircraft and Missile Surveillance and Threat Warning (Aircraft and Missile Detection/Typing, and NBC Signature Detection and Identification), and Support to Attack Operations (Target Identification/Status and Integrated Battle Damage Assessment). To support the Hyperspectral Imagery ITTP, AFRL is overseeing the Space-based Hyperspectral Support to Military Operations effort, which will provide the Hyperspectral Imagery ITTP with a key tool. This tool is a hyperspectral detection performance trade model, which is necessary to accomplish the ITTP's overall goal of developing an integrated, interactive, adaptive, space and air surveillance system.

Space System Survivability

Objective: Assure mission performance in the presence of natural and man-made threats



Protection Solutions to Assure Mission Performance

The objective of this program is to develop and demonstrate those technologies that increase the probability of mission success with space systems operating in the presence of natural and man-made threats. Three major thrusts comprise the present focus on protection of these space systems: Hazard/Threat Warning and Attack Reporting, Passive Protection Techniques and Active Survivability Enhancement Options. Capabilities derived from these thrusts will provide real-time hazard/threat detection, characterization, geo-location, and reporting; the ability, through hazard and threat-tolerant components and subsystems, to withstand low-level, hostile operating environments; and active techniques to avoid or counter advanced threats. The goal is to provide efficient, cost-effective, performance compatible protection solutions that assure mission performance in the presence of natural hazards and man-made threats.

Space Optics and Laser Technology

Objective: Revolutionize lasers and optical systems in space

Space-Based Optics and Laser

The program for space optics and laser technology is intended to complement the Ballistic Missile Defense Office (BMDO) Space Based Laser (SBL) Integrated Flight Experiment (IFX) program by opening up the range of options that can be considered for an SBL Engineering, Manufacturing and Development (EMD) decision. This means pursuing the development of alternate, high-payoff space-based optics and laser technologies, application concepts, and mission concepts reaching a level of technical maturity and demonstrating performance that supports the EMD decision process. Supporting initiatives include the investigation of technologies such as high-efficiency electric lasers and ultra-large aperture membrane optics, application concepts such as relay mirrors, and mission concepts for the negation of atmospheric targets and low-power missions such as battlefield surveillance and remote sensing.

4.1.3 FYDP Investment Strategy for Space Superiority ITT

In the near term, the Space Superiority ITTPs are focusing on the development of technologies that will enable low-cost access to space launch systems with multi-mission capability and interchangeable payloads. In addition, the technologies will provide the capability for ballistic missile defense coverage; automated target identification; undeniable, all-weather surveillance for ground moving target indication and airborne moving target indication and finally, threat detection, identification, source location, characterization, and reporting.

Table 4-2 on the next page summarizes the present ITTPs, the technologies being developed and the payoffs in terms of operational capabilities.

Space Superiority ITTP	Technologies Being Developed	Payoff
Space-Based Radar	• Antennas • Phenomenology – ionospheric clutter and target effects • Modeling and simulation – physics based on satellite systems, constellation and support infrastructure, campaign levels • Data fusing/processing • Materials and low weight structures	• Undeniable, all-weather surveillance • Ground moving target indication • Airborne moving target indication • Near-real-time information the battlefield • Rapid global revisit for any point
Hyperspectral Imaging	• Advanced structures and materials • Sensor/cooler components • Innovative E/O sensor designs • Bus component technologies • Automated target detection and identification algorithms • Atmospheric correction models • Autonomous, space-qualified data and information-processing technologies	• Target/background phenomenology characterization • Global statistical databases • Validated models of the optical properties of the environment • Automated target detection and identification algorithms • Camouflage defeat/material identification algorithms • Terrain categorization algorithms • Battle damage assessment techniques
Space System Survivability	• Hazard/threat warning sensors • Passive protection techniques • Active protection techniques	• Space asset situational awareness and unambiguous anomaly resolution • Space hazard and man-made threat mitigation • Mission survivability in stressing operational environments
Space Optics And Laser Technology	• High efficiency electric lasers • Devices options, power generation, thermal management • Ultra-light large space optics • Ultra-precise beam control • Alternate system concepts and architectures • Technologies for alternate missions	• High power SBL devices with infinite magazine • Increase in SBL range with no increase in weight • Improved cost effectiveness for TMD • Enable multi-use SBL/relay mirror platform

Table 4-2: Summary of Space Superiority ITTPs

4.1.4 Relationship of Other S&T Programs to the Space Superiority ITT

The foundations for the five Space Superiority ITTPs are technologies developed in the ETAs. Figure 4-2 shows the ETAs that will provide the components for the individual ITTPs.

There is a Memorandum of Agreement (MOA) between the AFSPC, AFRL and NASA for a DoD Space Launch Modernization Plan. NASA has the lead for the first stage and the Air Force leads multiple second stage options. The SOV first stage demonstrator will be built as part of NASA's Future X program while the Air

Enabling Technology Areas \ AFRL ITTPs	Space Based Radar	Space Operations Vehicle	Hyper-spectral Imaging	Space System Surviv-ability	Space Optics & Laser Technology
Space Vehicles	○	●	●	●	○
Directed Energy			○	○	●
Information	○	○	○		○
Sensors	●	○	○	○	○
Propulsion	○	○	○	○	
Air Vehicles		●			
Materials & Manufacturing	○	○	○	○	○

● = Lead ○ = Participating

Figure 4-2: Correlation of AFRL's Space Superiority ITTPs to ETAs

Force will concentrate on reusable SMV and expendable MIS upper stages. The Air Force S&T investment will be in militarily unique technologies.

4.1.5 Space Superiority ITT FY25 Vision

By 2025, enabled by the technologies developed under the Space Superiority ITT, the Air Force will have the ability to provide satellite systems with 100 times more load carrying capability at 10 percent of the system weight and 10 percent of the life-cycle cost. Undeniable, all weather, surveillance systems for ground and airborne targets, with interchangeable payloads, within two hours at a cost of $100 (FY98 $) per pound to low earth orbit (LEO) will be available. Tracking and characterization of moving, stationary, camouflaged, and sub-terrain targets to a resolution of less than .5 meters using radar and optical aperture greater than 1,000 meters will be achievable. On-orbit electric power in excess of 5 mega-watts will permit the use of high-power directed energy systems tailored to any wavelength and any power to permit engagement against any target. Finally, efficient on-orbit re-manufacturing and servicing to increase lifetime by 100 percent and enhance mission utility will be available to support operational space systems.

4.2 Precision Strike

"Swiftly Locate, Strike and Destroy Targets Throughout the Globe"

Many of the capabilities resident within the Air Force emanate from traditional air-to-air or air-to-ground missions. The value of power projection from airborne platforms using precision guided munitions was clearly demonstrated during Desert Storm. The ability to project power becomes even more important in Global Engagement. The Precision Strike ITT is addressing technology to enable an affordable capability to swiftly and flexibly deliver highly effective weapons against targets at any required global location. This ability to affordably destroy or neutralize any target on the earth will enable the execution of more missions from CONUS or forward base. The Precision Strike ITT will also deliver the flexibility to safely target enemy forces in urban locations as well as eliminate facilities associated with the production and employment of weapons of mass destruction.

4.2.1 Precision Strike ITT Planning Context

Joint Vision 2010 - Global Engagement is based upon a new understanding of what air and space power means to the nation - the ability to directly hit an adversary's strategic centers. Thus, one of the key operational concepts of Global Engagement is Precision Engagement. The Air Force, recognizing the importance of this concept, has further defined Precision Engagement as a required Air Force core competency. The Precision Strike ITT directly supports this Air Force core competency. Precision Strike, however, also involves comprehensive engagement management and, as such, is a key element of the Global Attack, Rapid Global Mobility and Information Superiority core competencies. Likewise, Precision Strike is the key element in the *Air Force Strategic Plan*. Common to these user needs is the requirement to quickly respond globally, which along with a need to reduce pilot exposure to threats, is driving the need for unmanned (combat) air vehicle (UAV/UCAV). The need to operate while under threat engagement is driving the need for advanced self-protection, such as laser hardening and countermeasures. Once a platform reaches a target, whether being engaged by a threat or not, the theater and operational commander along with the pilot, if any, needs the ability to Find, Fix, Assess, Track, Target and Engage (F2AT2E) the target in (near) real-time, day or night, under all weather conditions.

4.2.2 Precision Strike ITT Investment Strategy

The Precision Strike ITT will develop technologies to reach-out and destroy enemy forces. However, precision strike is more than just developing smart weapons. Precision Strike's investment strategy will also focus on real-time global "engagement management" of the platforms to deliver the weapon and the sensors to detect, assess and attack the target with fast, reliable, smart, low-cost weapon systems. Precision Strike will address dramatic improvements for war fighting in the areas of platforms, propulsion, information exploitation, survivability, precision targeting, and lethality. This system of systems approach is necessary to meet not only the *Joint Vision 2010* operational concept of Precision Engagement but also enables Dominant Maneuver and Full Dimensional Protection. In addition to addressing high level operational concepts, many of the technologies will solve or mitigate numerous deficiencies identified in the various MAJCOM Mission Area Plans initiated in response to the AFMPP. While concentrating on a family of technologies devoted to the pointed end of the spear, the Precision Strike ITT facilitates capabilities

Precision Strike ITTPs

- Unmanned Combat Air Vehicles
- Automatic Target Recognition
- Sensor Protection
- Electro-Optical Countermeasures/Infrared Countermeasures
- Small Smart Bombs
- Real-Time Sensor-to-Shooter Operations
- Low Cost Autonomous Attack Systems

provided by the other ITTs either by exploiting their information products or benefiting from their support.

The Precision Strike ITTP's that comprise the Precision Strike ITT are Unmanned Combat Air Vehicles (UCAVs), Automatic Target Recognition (ATR), Sensor Protection, Electro-Optical Countermeasures/Infrared Countermeasures (EOCM/IRCM), Small Smart Bombs (SSB), Real Time Sensor-to Shooter Operations, and Low Cost Autonomous Attack Systems (LOCAAS). The following are brief descriptions of each of the ITTPs.

Unmanned Combat Air Vehicles

Objective: Reduced system cost, increased operational flexibility and removal of pilot from harm's way

Remove Pilot from Harm's Way

This program will develop the capability for UAVs to go beyond present reconnaissance missions and to directly engage enemy forces. The program focuses on two fundamental combat capabilities: suppression of enemy air defenses and strike missions. The enabling technologies to be demonstrated address the whole scope of functional requirements essential to achieving the ability to flexibly strike enemy forces using UAVs. They include exploration of the human/UAV interface, command and control, weapons delivery and air platform design.

Automatic Target Recognition

Objective: The information to engage the most significant targets at precisely the optimum time

Real-Time Targeting Information

Multiplying sensor and information gathering assets challenge the abilities of analysts to rapidly process the data and identify the most critical targets. The ATR program will develop and demonstrate technologies needed to efficiently process the mountain of data and provide real-time targeting information to aircrews. The key technologies include commercial-off-the-shelf (COTS) computer and software tools, information fusion algorithms, and advanced sensors. Modeling and simulation and distributed processing technologies will enhance the ATR effort.

Sensor Protection

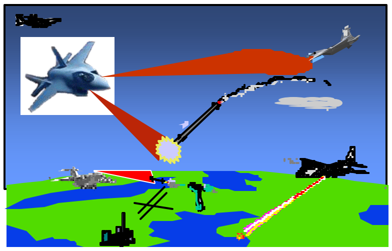
Objective: Assured receipt of critical information regardless of enemy denial attempts

Laser Eye Protection

Modern sensors are critical to the employment and lethality of precision weapons. They face a variety of threats, including laser and radio frequency (RF) weapons, which can blind or permanently degrade sensors. Hardening technologies for the protection of tactical and space-based sensors, including eye protection for aircrews, will be validated. The enabling technologies will be affordable, efficient and flexible enough to keep up with changing threats.

Electro-Optical Countermeasures / Infrared Countermeasures

Objective: The ability to conduct air operations globally with high success and minimal losses



Defeat Heat Seeking Missiles

The EAF operational strategy calls for a worldwide deployment and engagement capability. This strategy is threatened by the proliferation of small, inexpensive heat-seeking missiles that possess single shot lethality against all of our aircraft assets. The EOCM/IRCM program will demonstrate the ability to defeat the seekers of present and future heat-seeking missiles and retain the EAF commander's options to deploy and fight all over the globe with acceptable attrition rates. The enabling technologies to be demonstrated include advanced lasers, miniature high-accuracy pointing and tracking heads, advanced long-range missile warning systems, and advanced laser signal reception and exploitation techniques. The system demonstration requirements are scoped to allow affordable and rapid deployment on large, high-value aircraft like the C-17.

Small Smart Bombs

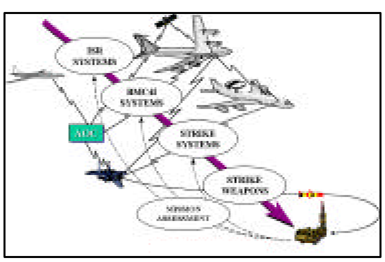
Objective: The ability to command more of the battlefield with fewer air assets

Small, Lightweight Bomb

The SSB program will provide enabling technologies to deploy a family of small, lightweight, precision guided bombs that exceed the accuracy and lethality of existing bombs while allowing more weapons to be carried. Specific technologies to be demonstrated include upgraded Global Positioning System (GPS), improved folding fins, autonomous terminal seekers, anti-jam GPS, improved smart fusing and improved blast and fragmentation warheads. The specific performance goals exceed the accuracy and range of the present MK-83/84 Joint Direct Attack Munition (JDAM) while retaining lethality against 85 percent of the JDAM target set in a 250-pound package.

Real-Time Sensor-to-Shooter Operations

Objective: Superior autonomous awareness to control and dominate the battlespace



Superior Autonomous Awareness

Current strike aircraft operate in a semi-autonomous manner, relying on existing communications and their own resources to employ their weapons against largely predetermined targets. Their flexibility, though much improved over the past, is still limited. AEF commanders will require strike aircraft to destroy the optimum target at the proper time to achieve the maximum warfare payback. Real-Time Sensor-to-Shooter Operations will develop and demonstrate the enabling technologies to link the strike aircraft to real-time information and make possible optimum targeting. Specifically, the focus is on integration of multiple information sources, using wide bandwidth data links, with time-critical decision resolution and data fusion capability. Real-time on-platform and off-platform architectures will be developed to process and employ the information and integrate processed data with advanced on-board sensors such as automatic target acquisition, recognition, and location systems.

Low Cost Autonomous Attack Systems

Objective: Elimination of the political and military threat posed by mobile weapons of mass destruction

Miniature Powered Munition

Moving, high-value targets present a difficult problem for even the most advanced integrated attack aircraft. High value target movement introduces uncertainty into the targeting equation regarding exact location and identification. LOCAAS will demonstrate an affordable, miniature, powered munition capable of locating, identifying and destroying mobile targets such as air defense and theater attack assets. The system demonstration will integrate laser radar sub-munition seekers with ATR algorithms on a loitering air vehicle employing a multi-mode warhead and a miniature turbojet engine.

4.2.3 FYDP Investment Strategy for Precision Strike ITT

Table 4-3 on the next page summarizes the present ITTPs, the technologies being developed, and the payoff to be realized on completion.

Precision Strike ITTPs	Technologies Being Developed	Payoff
Unmanned Combat Air Vehicles (UCAV)	• Air vehicle design • Air vehicle control • Cost Analysis • Human-Systems Interfaces	• 21st Century SEAD/Strike UCAV capabilities • Removal of pilot from harm's way • Low cost of mission accomplishment • Increased operational flexibility for EAF commanders
Automatic Target Recognition (ATR)	• High probability of identification flow false alarm ATR for autonomous munitions (LOCAAS, SSB) • On/off-board SAR/FLIR fusion for strike platforms • RF detection of many targets	• Automatic detection and identification in real-time, time-critical and time sensitive targets with high confidence within a broad area of interest • Multiple target radar identification of ground moving targets for JSTARS, Global Hawk U2R & for combat aircraft
Sensor Protection	• Laser hardened detector materials for air and space application • Counterspace passive and active protection technologies • Threat warning/attack reporting	• Aircrew spectacles which protect eyes from known high probability threat lasers • Advanced filters for tactical and space EO/IR sensors • Laser hardened FLIR system • Hardening techniques for future multispectral focal-plane-array based sensors • Tunable protection for night vision goggles
Electro-Optical Countermeasures/ Infrared Countermeasures (EOCM/IRCM)	• High power solid state lasers • Multispectral missile warning & track • Laser closed- or open-loop missile seeker degradation & destroy (D2)	• High power multi-band laser source for IRCMs to protect large aircraft • Laser D2 CM for advanced threat missile EO/IR/laser trackers
Small Smart Bombs (SSB)	• Guidance and control • Compact, integrated antijam inertial navigational system (INS)/GPS guidance; fast GPS acquisition; folding fins • Folding wing kit • Warhead • Enhanced fragmentation/blast warhead • Multiple event fuzing and detonation sequencing • LADAR terminal seekers	• Small (250 lb) precise, stand-off attack munition for fixed surface targets with greatly expanded lethal footprint that has: • Terminal LADAR seeker to negate target location error • Miniature anti-jam GPS INS • Multi-event hard target fuze • Improved blast yield high energy explosive
Real-Time Sensor-To-Shooter Operations	• High performance knowledge bases • Improved real-time embedded computers/processors • COTS leveraged cost reduction • Active database technology	• Autonomous operations with maximum effectiveness • Advanced, multi-ship, SEAD targeting • Off-board targeting feeds to inertial helmet mounted tracker
Low-Cost Autonomous Attack Systems (LOCAAS)	• Multimode warhead for all ground mobile targets • LADAR wide area seeker • High lift airframe • Miniature turbojet engine	• Minimized risk to aircraft and crew conducting SEAD mission • Low cost autonomous munition for search and destroy over large search area • More flight time to seek the best target

Table 4-3: Summary of Precision Strike ITTPs

4.2.4 Precision Strike ITT

The foundation for the seven Precision Strike ITTPs is technologies developed in the ETAs. Figure 4-3 shows the ETAs that will provide the components for the individual ITTPs.

AFRL ITTPs / Enabling Technology Areas	Unmanned Combat Air Vehicles	Automatic Target Recognition	Sensor Protection	Electro-Optical Counter-measures Infrared Counter-measures	Small Smart Bombs	Real Time Sensor-to-Shooter Operations	Low-Cost Autonomous Attack Systems
Space Vehicles		❍	❍			❍	
Directed Energy				❍			
Information	❍	❍				●	
Sensors	❍	●		●	❍	❍	❍
Munitions	❍	❍			●	❍	●
Propulsion	❍						
Air vehicles	●				❍		❍
Human Effectiveness	❍					❍	
Materials & Manufacturing	❍		●	❍			

● =Lead ❍ =Participating

Figure 4-3: Correlation of AFRL's Precision Strike ITTPs to ETAs

4.2.5 Precision Strike ITT FY25 Vision

The Precision Strike ITT long-term vision leverages the precision strike platform, sensor, weapon and engagement management technologies to achieve several demanding goals. In the realm of military tasks, this vision includes locating 95 percent of unhidden targets and 80 percent of hidden targets with minimal degradation because of adverse weather conditions. This will be done while maintaining tracking quality on all identified mobile targets so they can be acquired and successfully engaged with 95 percent confidence. With the targets identified and tracked, the targets of interest will be engaged with 95 percent or greater confidence of mission success. After the target has been attacked, target engagement effectiveness will be assessed with 95 percent confidence within minutes to hours depending on specific target priority. Thus, the entire F2AT2E cycle will be conducted within 10 minutes for time-critical targets and within two hours for time-sensitive targets. The result will be a 10-fold reduction in EAF strike asset airlift footprint requirements.

4.3 Information Dominance

"Collect, Control, Exploit and Defend Information While Denying an Adversary the Ability to do the Same"

Information Dominance is defined as the ability to collect, control, exploit and protect information, while denying our adversaries the ability to do the same. Information technologies and access to information products are changing and evolving at an unprecedented pace. It is essential that the unique requirements that are placed upon military systems and specifically within the fast paced distinctive environment of the Air Force, evolve ahead of the commercial world. Traditional targets in the information age have changed – banking systems, control systems for railway operations, air control systems, control systems for pipelines, media systems, and others. Only a fraction of these are preliminary military or under the direct protection of the Department of Defense. The civilian sector is no longer a sanctuary that can be protected by interposing military forces between adversaries and their targets. Traditional military forces can be flanked at the speed of light by information age attacks on the general population or key economic systems. More profoundly, there is no consensus on the appropriate boundary between the military and Department of Defense roles and missions and those of the law enforcement, intelligence systems, and the commercial sector. In fact, in the future, military advantage will be achieved, maintained and exploited by access control, rapid processing and the exploitation of information. Information dominance enables economy of force and creates a more lethal battlespace, facilitates increases in operations tempo, and makes it possible for the US to retain the initiative during any conflict.

4.3.1 Information Dominance ITT Planning Context

To achieve the *Joint Vision 2010*, the Air Force has established a vision of Global Engagement. One of the core competencies that the Air Force has identified to realize the capability of Global Engagement is Information Superiority. Information superiority, or information dominance, also inherently supports the other Air Force core competencies: Air and Space Superiority, Global Attack, Rapid Global Mobility, Precision Engagement and Agile Combat Support. The *Air Force Strategic Plan* has established overarching goals to develop these core competencies. Information dominance is inextricably interwoven into three of these goals: Conduct Seamless Operations to Control the Aerospace Dimension; Find, Fix, Assess, Track, Target and Engage (F2AT2E) any target of significance; and be an Expeditionary Aerospace Force (EAF). Integration of air and space to achieve seamless operation is reliant on Information Dominance to achieve unity of command and purpose with greater overall force effectiveness. Inherent in this information dominance concept is the ability to provide a commander with global awareness and global information exchange. Global awareness and information exchange will in-turn make F2AT2E possible. This will enable joint forces to operate free from attack, and have the freedom to attack. Information Dominance will also enable the Air Force to rapidly initiate and sustain aerospace operations anywhere in the world. The total asset visibility and dynamic planning capabilities resulting from or enabled by Information Dominance will enable the EAF to realize its goals of 24/48 hours fighter/bomber on target.

4.3.2 Information Dominance ITT Investment Strategy

Information Dominance ITTPs

- Consistent Battlespace Picture
- Global Grid
- Dynamic Command and Control
- Configurable Aerospace Command and Control
- Defensive Information Warfare

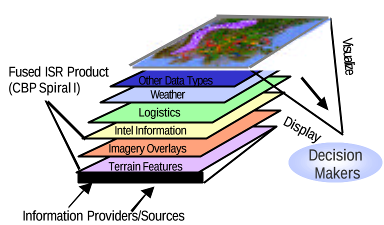
Technology has, for many years, provided various ways to collect, control, exploit, and defend information while denying the adversary the same capability. But achieving Information Dominance, in order to assure Global Awareness and Global Exchange, requires a more specific technology focus. The Information Dominance ITT investment strategy is to develop a fused intelligence, surveillance and reconnaissance product that integrates geospatially referenced data with data access, storage and retrieval technology, with all source data fusion and trend analysis. Functional command center reconfiguration based on operator performance, concomitant with on-board adaptive operator training, and mixed (human/machine) initiative planning technology will be developed as an interim step towards dynamic planning and execution monitoring capability.

EAF concepts will require global connectivity. The Information Dominance ITT investment strategy includes the integration of airborne satellite communications (SatCom), air-to-air local area networking, reach back and global resource management, as well as spiral demonstrations and deliverables of information protection products. Also included will be interactive information operations decision support tools, adaptive multi-level security and distributed forensic capability and tools, and techniques for non-real-time automatic information asset recovery and reconstitution.

To meet all of these needs, five ITTPs have been established: Consistent Battlespace Picture, Global Grid, Dynamic Command and Control (DC2), Configurable Aerospace Command and Control, and Defensive Information Warfare. The objectives of these programs and brief descriptions of each are included below.

Consistent Battlespace Picture

Objective: A complete picture of the battlespace for commanders to plan and execute all aspects of a war



Data Storage Capacity and Information Access

To achieve many aspects of dynamic planning and execution on the battlefield, a real-time, all-source, data-fused operating picture will be developed using hardware and software to generate and display with precision and registration, terrain and feature maps, weather, and imagery. Multiple sources of information will be fused to generate a family of overlays including hostile targets, opposing forces, friendly forces, and the logistics footprint. The Consistent Battlespace Picture in the future is anticipated to require large amounts of storage capacity and extremely fast information access.

Global Grid

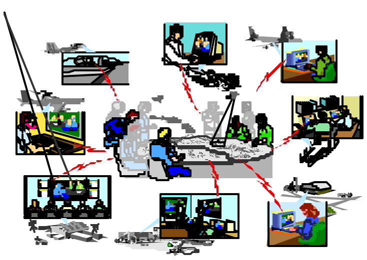
Objective: A global communications network for real-time command and control

Global Communications Network

Secure connectivity hardened against electronic attack will be developed to disseminate information from the command centers to the battlefield. Airborne and spaceborne assets require large bandwidth to facilitate the movement of time-critical information across dynamic communications links and networks with secure survivable network protocols. The Air Force will require a fully and seamlessly interconnected network of communications resources to provide assured information flows to, from, and within the battlefield. The Global Grid is a virtual, multi-dimensional grid of interconnected information and communications systems that makes possible global connectivity for C2 elements and organizations. Functionally, the Global Grid uses the capabilities provided by defense, national, commercial, and international communications resources. The Global Grid ITTP addresses many deficiencies and emphasizes support for the emerging EAF mission.

Dynamic Command and Control

Objective: Planning, controlling and execution of aerospace forces in a joint coalition environment



Planning and Scheduling Environment

The Air Force is moving from a platform-centered organization to an air and space power in an information-centered environment. DC2 will provide timely, flexible C2 across a spectrum of aerospace activities: force support (logistics); force application (shooter); force enhancement (intelligence, surveillance and reconnaissance); and air superiority (defensive air). In order to successfully accomplish this, three key information technologies areas are being researched and developed. They are knowledge-based planning and scheduling, high performance knowledge bases, and intelligent agent-based systems. Combined they provide the capability to effectively use information in a continuous planning and scheduling environment. This will create the dynamic environment necessary to improve situational awareness, decrease re-planning response time, and provide accurate asset tracking with a greater number of plan options. C2 technologies developed under this ITTP will be highly flexible. These technologies will be demonstrated through a series of integration experiments designed with operational performance metrics.

Configurable Aerospace Command and Control

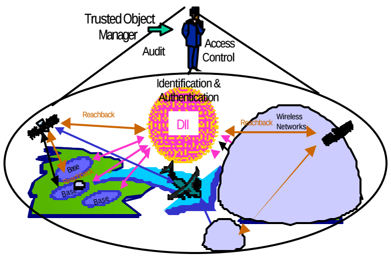
Objective: Physically scalable, functionally adaptive, time sensitive expeditionary command and control

Configurable Aerospace Command Center

With increasing emphasis on fast, reconfigurable force employment and deployment operations, command and control centers, infrastructure, and information support systems must adapt to changes in mission profile as well as physical and functional resource requirements. The C2 systems of the future must evolve and adapt to changing operational environments without requiring the time-consuming and labor-intensive configuration changes needed for current deployments. The Configurable Aerospace Command and Control center will provide and demonstrate technology and capabilities to forward deployed elements of the EAF. It will encompass adaptive (intelligent) switching interfaces to the global grid and will integrate mission training, rehearsal, and simulation to achieve mission objectives. It will include maturing adaptive decision support tools that contribute to the capabilities necessary for distributed operations. As a team, warfighters and technologists will define, develop and demonstrate these capabilities against operational metrics through prototypes and exercises.

Defensive Information Warfare

Objective: Survivable information systems and network technology



Survivable Network Technology

To operate in an information rich environment, the Air Force must defend itself from information warfare attack and, if attacked, recover as quickly and effectively as possible. Survivable network technology for protection of secure systems is needed. An indications and warning knowledge base to accurately detect early intrusions upon both strategic and tactical information systems needs to be developed. The computer and data forensics area will develop tools to recover from attack, gather evidence for courses of countering the attack, and analyze future actions to avoid these intrusions.

4.3.3 FYDP Investment Strategy for Information Dominance ITT

Table 4-4 on the next page summarizes the present ITTPs, the technologies being developed, and the payoffs in terms of new operational capabilities to be realized upon completion.

Information Dominance ITTPs	Technologies Being Developed	Payoff
Consistent Battlespace Picture	• Multisensor exploitation • Conflation (map accuracy) • Multi-database integration & update • Off-Board Augmented Theater Surveillance • Expert systems technology • Complex information visualization	• Common view of battlespace across all dimensions: air, space, cyber, surface, subsurface • All-source fusion module • Geospatially-referenced multi-source database • Large volume mass storage, high-speed data access and retrieval technologies
Global Grid	• Low profile multiband (MB) antennas • Low probability intercept/low probability detection waveforms • Real-time link management • Intelligent network management • Reconfigurable protocols • Multi-domain network management • Universal information transactions • Integrated network and information management system • Deployable information based on mission	• World-wide in-transit visibility and link management for mobility assets • Extended beyond-line-of-sight communications capacity "reachback" • Guarantee assured access survivability of commercial systems • Low cost high-bandwidth, high data rate airborne communications systems • Media access controller for internet-like information access from/to aircraft • Manned aircraft demonstration of airborne communication node functionality (communication relay, on-board switching)

Dynamic Command and Control	• Knowledge-based planning and scheduling
	  – High performance planning algorithms
	  – Unified context capture/exploitation
	• Intelligent agent-based systems
	• Uncertainty information-based planning
	• Cross-functional planning systems
	• High performance knowledge bases
		• Multi-national air campaign planner
		• Crisis action response planner for Special Operations Forces
		• Interactive computer assisted planning
		• UCAV planning tool
		• Improve planning process (plan, monitor, replan in near real-time)
		• Deconflict tasks in coalition operations
		• Rapid adaptation to time-critical, variable-level crises

Configurable Aerospace Command and Control	• Industry standard distributed computing architecture • Intelligent agent for configuration • Application software portability • Integrated (systems, applications) resource management • Measures of effectiveness monitoring, analysis and action	• Dynamic information tailoring • Able to configure center to adapt to changing roles (warfighting, peacekeeping, humanitarian) • Re-configurable, distributed, collaborative C2 cells • Integrated, enhanced, visualization collaboration and decision support tools • Built-in operator/team performance monitoring, training
Defensive Information Warfare	• Survivable information systems • Vulnerability assessment / risk management tools • Information operations sensors • Damage assessment, recovery & forensics	• Information operations sensors • Damage assessment, recovery, and forensics tools for information attacks • Security shields for commercial off-the-shelf products • Planning awareness and decision support tools

Table 4-4: Summary of Information Dominance ITTPs

4.3.4 Relationship of Other S&T Programs to Information Dominance ITT

The foundation for the five Information Dominance ITTPs are enabling technologies developed in the ETAs. Figure 4-4 shows the ETAs that will provide the components for the individual ITTPs.

Enabling Technology Areas \ AFRL ITTPs	Common Battle-space Picture	Global Grid	Dynamic Command And Control	Configurable Aerospace Command and Control	Defensive Information Warfare
Space Vehicles	❍	❍	❍	❍	❍
Information	●	●	●	●	●
Sensors	❍	❍		❍	❍
Human Effectiveness	❍		❍	❍	❍

● = Lead ❍ = Participating

Figure 4-4: Correlation of AFRL’s Information Dominance ITTPs to ETA's

4.3.5 Information Dominance ITT FY25 Vision

In 2025, enabled by the technologies developed under the Information Dominance ITT, the Air Force will have the ability to establish and maintain complete situational awareness of a theater battlespace, including precise, timely information on hard targets (low observable, hidden and sub-surface targets). This will include the ability to tailor the real-time battlespace picture to each decision-maker. In addition to the battlespace picture, a commander will have continuous 24 hour in-transit visibility of resources (supplies and people) and global connectivity to all aerospace forces. All of this information will be available anywhere in the world on-demand. Having this information will enable each decision-maker to use real-time simulations to weigh alternative courses of action. All of this will be accomplished by reconfigurable command and operation centers that will have a footprint that is reduced by two orders of magnitude from that of today.

4.4 Aircraft Sustainment

"Maintain the Safety and Readiness of the Aging Aircraft Fleet"

The Air Force presently spends $27 billion a year to sustain their current aircraft fleet. The expected service life for these aircraft is being dramatically extended beyond their planned service life. Table 4-5 shows the average age of these aircraft. Unless sustainment technologies are developed and transitioned, this aging fleet will have increased operational and support costs, with a decrease in airworthiness and aircraft availability. In addition to the aging system sustainment issues, newer systems with advanced materials and designs often require the development of new sustainment technologies. The goal of the Aircraft Sustainment ITT is to provide the technologies needed to reduce sustainment costs while maintaining force readiness.

Aircraft Type	Ave. Age	Comment
B-52G/H	39	Retain 30+ years
KC-135	39	Retain 40+ years
C-141B	34	Retire in next 8+ yrs
T-38	33	Retain 25+ years
C-5A	29	Retire 20+ yrs
C/NC-130	24	Retire 30+ yrs
E-3	21	Retire 17-25 yrs
F-15 A-D	18	Retire 20+ yrs
A-10	15	Retire 25+ yrs
F-16 A-D	12	Retire 20+ yrs
All Aircraft	22	For 6,300+ Aircraft

Table 4-5: Overview of the Aging Aircraft Fleet

4.4.1 Aircraft Sustainment ITT Planning Context

Sustainment problems are forecast to increase dramatically in coming years because many aircraft are being used past their anticipated service life and will require extensive modifications to maintain airworthiness. The aging aircraft situation not only impacts the *Joint Vision 2010* Focused Logistics operational concept but also the Air Force's ability to effectively fulfill the other three *Joint Vision 2010* operational concepts of Dominant Maneuver, Precision Engagement, and Full-Dimensional Protection. All of these concepts have key elements reliant on the availability of aircraft to perform identified functions. Without enhanced life extension technologies, reduced aircraft readiness will degrade aircraft availability. In addition, the economic burden of maintaining this aging fleet will impact force modernization. The aging fleet directly impacts all six of the Air Force core competencies: Air and Space Superiority, Global Attack, Agile Combat Support, Precision Engagement, Information Superiority and Rapid Global Mobility. Without sustainment technologies, aging aircraft are an impediment to the Air Force strategy of being an EAF.

The National Research Council's National Materials Advisory Board has examined the aging fleet issue and recommended and prioritized technology needs in fatigue, corrosion fatigue, stress corrosion cracking, corrosion prevention and mitigation, nondestructive evaluation/inspection (NDE/I), maintenance and repair, and failure analysis and life prediction methodologies. There is a heightened need to determine airframe economic service life, including quantification of structural corrosion effects. The AFMPP identified similar issues, along with aircraft health monitoring, optimized advanced composite repairs to cracked metallic structures, extending storage life of subsystems/equipment/materials beyond design life, pollution prevention and reduction, implementation of less cumbersome support packages, increased phase/preventive maintenance intervals, and reduced phased depot maintenance (PDM) turn-around times.

Sustainment is not totally an aging issue. Advanced systems entering service also often create sustainment issues. For example, the low observable materials now being used are subject to in-service damage and require new field-level repair concepts. Also, new high performance engines are stressing materials and causing unanticipated material failures. Replacement materials, or life extension techniques, are needed to reduce sustainment issues with these engines.

4.4.2 Aircraft Sustainment ITT Investment Strategy

Aircraft Sustainment ITTPs

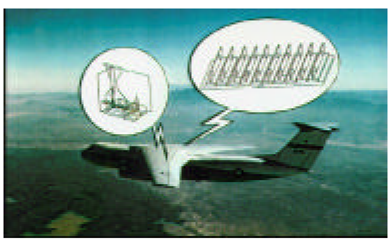
- Aging Aircraft Structures
- Low Observable Maintainability
- High Cycle Fatigue
- Turbine Engine Durability

The Aircraft Sustainment ITT is dedicated to the formulation and evaluation of emerging technological advancements in the areas of maintenance cost savings and life extension for current and future aircraft systems. The investment strategy is to concentrate on the aging aircraft sustainment issues, identified by the National Materials Advisory Board, while addressing the top two or three most important non-aging issues. The Aging Aircraft issues identified by the National Materials Advisory Board included corrosion, stress corrosion cracking, fatigue cracking, nondestructive evaluation, and structural maintenance and repairs. While working with its customers, AFRL has identified the three most important non-aging issues to be repair of low observable materials, high cycle fatigue of engine components, and turbine engine durability.

To meet these needs, four ITTPs have been established: Aging Aircraft Structures, Low Observable (LO) Maintainability, High Cycle Fatigue (HCF) and Turbine Engine Durability. The technical objective and a brief description for each of the ITTPs are provided below:

Aging Aircraft Structures

Objective: Extended aircraft life, reduced maintenance cost and increased operational readiness

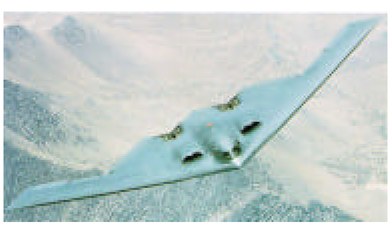


Structural Integrity Analysis Techniques

The aging aircraft structures ITTP is a collection of technology programs targeting the development of advanced structural integrity methodology; advanced NDE/I systems; improved corrosion prevention, assessment, and control; and repair and replacement technologies to assure the airworthiness of aging aircraft and to enable fleet management. Technologies will include enhanced tools for predicting structural service life and maintenance causing events; new protective coatings; methods for early detection of corrosion and for detection of hidden corrosion; characterization of corrosion damage and its impact on structural integrity; repair guidelines and procedures; criteria for maintenance actions; and others.

Low Observable Maintainability

Objective: Efficient field-level repair capabilities for advanced stealth systems



Low Observable Maintenance

The LO Maintainability ITTP is a collection of programs aimed at the maintenance of LO technologies affecting the mission capability rate of several advanced aircraft. The LO materials on these aircraft are subject to both in-service (rain, hail, etc.) damage and to on-the-ground handling damage. Present caulks and adhesives have excessively long cure rates and NDE/I techniques to validate integrity of repairs are inadequate. The aim of the programs is to develop field level maintenance methodology to ensure fleet readiness of these high technology aircraft. Programs will address materials, application technologies, and nondestructive evaluation methods to assure the electromagnetic integrity of the repairs. Present programs are focused on LO gap treatments, new adhesives, and LO NDE/I. Near term efforts will also address repair of radar absorbing materials and structures.

High Cycle Fatigue

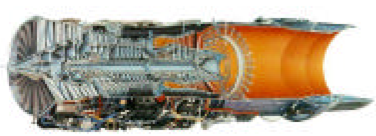
Objective: Eliminate HCF-related class "A" mishaps, reduce shutdowns 50% and maintenance costs 15%

High Cycle Fatigue Failure

Present turbine engine design techniques consider HCF independent of low cycle fatigue, fretting and galling, and foreign object damage. This design approach has failed, leading to HCF failures early in the engine life. HCF induced engine failures have resulted in the loss of 3-4 fighters per year. Excessive engine maintenance is costing the Air Force over $1.3B per year. This ITTP targets engine related HCF problems with programs concentrating on damage tolerance, instrumentation, forced response prediction, passive damping, aeromechanics characterization, structural analysis, surface treatments, and engine health monitoring.

Turbine Engine Durability

Objective: Increased engine life and reduced rotating hardware costs



Increase Engine Life

The Air Force currently spends $2.8B per year for turbine engine maintenance, 60% of which is hardware replacement costs. As new turbine engines are being designed to operate at higher temperatures and speeds, the materials and structures needed to meet these operating requirements are placed under severe stress. The engine environment of tomorrow will stretch the limits of our structural design, analysis, and instrumentation capabilities. Because of these conditions, critical flaw sizes become much smaller and, thus, very difficult and more expensive to find. Similarly, Foreign Object Damage (FOD) and material flaws necessitate the use of new probabilistic rather than deterministic life prediction and analysis techniques. The temperature and stress levels of components in this more hostile engine environment will have to be determined with greater accuracy in order to avoid catastrophic failure. This ITTP targets reducing hardware replacement, enhanced durability models, probabilistic life analysis, reliable small-crack detection techniques, innovative hot section cooling and coating techniques and engine health monitoring technologies needed to ensure future fighter engines have even better reliability, robustness of design, and cost effective maintainability than today's turbine engine fleet.

4.4.3 FYDP Investment Strategy for Aircraft Sustainment ITT

Table 4-6 on the next page summarizes the present ITTPs, the technologies being developed, and the payoffs to be realized upon completion.

Aircraft Sustainment ITTPs	Technologies Being Developed	Payoff
Aging Aircraft Structures	• Structural integrity analysis techniques • Repair & replacement technologies • NDE for corrosion and micro-cracking • Service life estimate tool set	• Extend structural life of existing fleet • Reduce cost of ownership • Accurately determine aircraft service life • Long life environment-friendly coatings • Reduced maintenance time and improved operational readiness
Low Observable Maintainability	• Intrinsically conductive elastomers gap treatments • Durable, quick cure sealants/adhesives for flight line repair of radar absorbing materials (RAM) & radar absorbing structures (RAS). • Hand held NDE devices for RF and optical measurements and inspection data fusion	• Reduced maintenance manhours per flight hour for flightline repairs for RAM & RAS • Increased readiness and affordability • Point inspection techniques for verification of LO radio frequency (RF) and infrared (IR) properties
High Cycle Fatigue and Turbine Engine Durability	• Robust forced response analysis tools for shroud component analysis, aero mechanical characterization of bladed rotor mistuning and forced response prediction of flutter and resonant response • Joint service guide spec to help prevent HCF in future engines • Laser shock peening component surface treatments such as fan blade leading edges to enhance damage tolerance • Viscoelastic, particle, and powder passive damping methods to significantly lower dynamic stresses • Non-intrusive instrumentation/prognostics • Significantly improved damaged materials models to better define tolerances • Probabilistic life prediction and analysis techniques • Highly reliable, inexpensive small-crack detection techniques • Modernized testing protocol • Residual stress measurement and management • Advanced turbine oxidation and thermal coatings • New turbine cooling technology	• Fix for HCF failure of F119 1st stage fan • Safety goals - Reduce HCF-related non-recoverable in-flight shutdowns by 50% - Virtually eliminate HCF-induced engine failures in Class A mishaps • Readiness goals - Virtually eliminate HCF-related precautionary stand downs • Cost goals - Reduce engine maintenance costs 15% - Reduce fuel expended by 40% - 50% reduction in rotating hardware costs

Table 4-6: Summary of Aircraft Sustainment ITTPs

4.4.4 Relationship of Other S&T Programs to the Aircraft Sustainment ITT

The foundations for the four Aircraft Sustainment ITTPs are technologies developed in the ETAs. Figure 4-5 shows the ETAs that will provide the components for the ITTPs.

AFRL has ongoing interactions and joint endeavors with industry, the FAA, NASA, Department of Transportation (DoT), and other DoD agencies to ensure maximum return on investment for the development of these sustainment technologies. Activities such as joint conferences, symposia, and integrated

AFRL ITTPs / Enabling Technology Areas	Aging Aircraft Structures	Low Observable Maintain-ability	High Cycle Fatigue	Turbine Engine Durability
Propulsion			●	●
Air Vehicles	❍		❍	
Materials & Manufacturing	●	●	❍	❍

● = Lead ❍ = Participating

Figure 4-5: Correlation of AFRL's Aircraft Sustainment TTPs to ETAs product team activities ensure active cross-flow of information to the benefit of all participants. The current area of high interest is corrosion inspection, modeling and repair using environmentally friendly techniques. Other areas include interactions with the FAA on structural fatigue of transport type aircraft and replacement of Kapton wiring. Also, the Air Force has 215 helicopters with an average age of 21 years – including 70 HH and UH-1s that average 30 years in service. Under Joint Directors of Laboratories (JDL) Project Reliance planning, the Army has the lead in developing sustainment technologies for rotary-wing aircraft for both the Air Force and the Army.

4.4.5 Aircraft Sustainment ITT FY25 Vision

The long-term objective is to arrest aircraft maintenance cost growth and reduce the overall economic burden of maintenance on Air Force operations. This improvement is essential to free resources for modernization. One long-term goal is to reduce operations costs by cutting logistics support requirements by 75 percent. Others include a move to condition-based maintenance, extending structures two to three times their design life, reducing HCF class-A mishaps to less than one per year, extending engine life to 16,000 tactical cycles, making LO technology transparent to aircraft maintenance, and providing corrosion preventive paint coatings to last the aircraft's design life.

4.5 Agile Combat Support

"Improve Capability To Prepare And Deploy Responsive Forces In Support Of Multiple Deterrent Options"

In a turbulent and unpredictable world, with our nation facing unprecedented change, uncertainty and significant reduction in resources, the Air Force is realigning its strategies and concepts. A fundamental change is the move towards a contingency focused global expeditionary aerospace force (EAF) - one that is agile, responsive and effective across a wide range of potential scenarios in operational deployments worldwide. The challenge is to evolve from a threat-based Cold War garrison force, focused on containment, to a capabilities-based expeditionary force focused on responsiveness. The expeditionary force concept mandates a force that is "light, lean and lethal." Light means a reduced airlift requirement; being lean means operating out of austere locations with minimal resupply; and to be lethal, the EAF will have to create decisive effects and accomplish the mission effectively with minimum resources. Changes such as these dictate that new ways of doing business need to be developed. One of these new ways of doing business is an approach to combat support called Agile Combat Support (ACS).

4.5.1 Agile Combat Support ITT Planning Context

The National Military Strategy has shifted to employ a wide spectrum of military capabilities required to support differing geopolitical objectives. *Joint Vision 2010* outlines the replacement of the old combat support philosophy with one that will enable joint forces of the future to be more adaptive. Specifically, it calls for combat logistics to be more responsive, flexible, and precise, and is embodied in the operational concept of Focused Logistics. The Air Force vision of Global Engagement defines the way it will conduct business through its core competencies to meet the challenges set forth in *Joint Vision 2010*. ACS is the Air Force core competency that establishes the role of the logistics and combat support communities in the Global Engagement philosophy. In keeping with the strategic support objectives set forth in *Joint Vision 2010* and Global Engagement, AFMC identified ACS as its leading objective in its strategic plan. By 2005, AFMC intends to define reliability in ACS and provide it 95% of the time for the EAF. As the S&T arm of AFMC, the AFRL also identified ACS as one of its ITTs.

Agile Combat Support broadens the focus of combat support towards rapid movement of small, independent force packages to employ precise combat power anywhere in the world. Under ACS the focus of the support system shifts from maintaining massive inventories at overseas locations to establishing a rapid response capability. In addition to reducing deployment time and airlift, ACS focuses on reduced mobility footprint and base operations, a flexible deployed infrastructure, streamlined inventory and rapid, accurate, time-sensitive reach back. In order to accomplish its operational objectives, ACS has been organized into 3 distinct phases: readiness, deployment, and employment.

4.5.2 Agile Combat Support ITT Investment Strategy

Readiness, Deployment and Employment

Agile Combat Support ITTPs

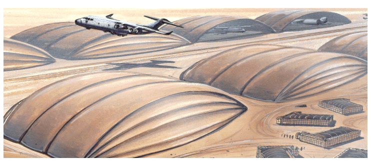
- Deployed Base Support Systems
- Deployment Planning, Command & Control,
  Reduced Airlift and Sustainment
- Force Protection

For the three ACS phases of readiness, deployment and employment, there are multiple operational and functional requirements which contain literally hundreds of potential research and technology development opportunities. By working with the user community and mapping current and planned Air Force S&T programs against these requirements, technology "gaps" will be identified and prioritized. Technology programs intended to fill these prioritized "gaps" forms the basis of the investment strategy within the current ACS ITT. In the near term, new ACS ITT initiatives will focus on increasing deployment planning speed, improved material handling equipment, force protection, and reducing the airlift and footprint required by base support functions and equipment at deployed locations.

ACS investments are primarily organized around two major themes. The first set focuses on programs to reduce the deployment footprint. The Deployed Base Support Systems ITTP and the Deployment Planning, Command & Control (C2), Reduced Airlift and Sustainment ITTP fall into this category. The second major theme includes those sets of programs that will protect the deployed forces. The Force Protection ITTP and the Active Denial Technology (ADT) ITTP fall into this category. The technical objectives and a brief discussion for each ITTP are discussed on the following page.

Deployed Base Support Systems

Objective: Faster, smaller, lighter, more efficient support structure for deployed units



Air Inflatable Thermal Resistance Shelters

This ITTP is designed to reduce weight/volume, airlift, set-up time and costs associated with delivering logistics support to deployed bases. It concentrates on mission-critical support facilities and functions for mobile air bases. These programs include air inflatable thermal resistance shelters, alternate power generation and distribution, and deployed airfield assessment systems. This ITTP focuses on minimizing the size of support structure materiel.

Deployment Planning, Command and Control, Reduced Airlift and Sustainment

Objective: Focused logistics to maximize use of inventory, reduce footprint and speed up response time

Increase Logistics Readiness

This ITTP is designed to develop a coherent management approach that will allow the Air Force to optimize the deployment of materiel and weapon systems. Its objectives are to increase combat forces' logistics readiness, develop and certify assessment tools to verify low observable repair capability and to develop technologies that improve Air Force cargo movement systems.

Force Protection

Objective: Enhanced security against conventional weapons and weapons of mass destruction

This ITTP is developing agile combat support technologies to protect deployed forces from conventional and non-conventional ground operating threats. Emphasis is on protecting rapid, light, forward deployments. Technologies include threat assessment and risk management tools, blast protection, remote threat detection and identification, and health risk assessment capabilities.

Active Denial Technology

Objective: Provide low collateral damage option to field commanders

The ADT ITTP is a set of classified, non-lethal directed energy technologies. Its objectives are to develop, demonstrate, and transition cost effective high-energy sources and power technologies.

4.5.3 FYDP Investment Strategy for Agile Combat Support ITT

Table 4-7 summarizes the present ITTPs, the technologies being developed, and the payoffs in terms of improved capabilities to be realized upon completion.

Agile Combat Support ITTPs	Technologies Being Developed	Payoff
Deployed Base Support Systems	• Deployable pavement repair system • Reduced footprint air inflatable chemical/thermal resistant shelters • Deployable power distribution systems • Lightweight aircraft parking aprons	• Reduced airlift to transport expeditionary unit • Reduced time/manpower to prepare and bed down initial support for shooters • Reduced footprint and manpower of shelter, power, waste control, and airfield runway assessment/repair systems
Deployment Planning, Command and Control, Reduced Airlift and Sustainment	• A suite of logistics planning and deployment tools • Deployed low observable support technology • Modular aircraft support systems • Advanced cargo handling systems • Aircraft battle damage assessment and repair technologies • Technologies to extend tire life • Systems to increase information for the warrior • More efficient distributed Air Ops Center (AOC) • Joint Forces Air Component Commander (JFACC) battle management program • Global/theater weather prediction methods • Small smart bomb • Low cost autonomous attack system	• Flexible deployment planning decision-aiding tools for wing-level logistics managers to quickly adjust to change in EAF deployments • Reduced footprint and airlift requirements for multi-purpose material/cargo handlers equipment with added reliability and maintainability • Enhanced low observable flight line diagnostics and repair capabilities at deployed locations • Gives JFACC full AOC capabilities, without deploying a full AOC • Increased ability for predicting impact of weather on weapons effectiveness • Reduced airlift requirement
Force Protection	• Deployable, small footprint remote threat detection sensors for personnel and vehicles • Expanded situational awareness insertions • Chemical agent on a chip • Global ionospheric impacts on combat • Space based radar • High strength lightweight blast protection materials and methods	• Improved threat detection and physical protection systems for deployed forces against a variety of threats: deployed operations, asymmetric threats, conventional threats • All weather remote ground/air threat detection and characterization • Rapid detection reporting and destruction of chemical and biological agents • Increased ability to find and identify targets • Increased accuracy of navigation systems
Active Denial Technology (ADT)	• High energy sources • Target detection, location and identification • Recognition and sensing radar • Man-portable ADT technologies	• Suppression of enemy C2 • Deep magazine, area beam weapon • Provides low collateral damage option to field commanders

Table 4-7: Summary of Agile Combat Support ITTPs

4.5.4 Relationship of Other S&T Programs to the ACS ITT

The foundations for the four ACS ITTPs are technologies developed in the ETAs. Figure 4-6 shows the ETAs that will provide the components for the individual ITTPs.

The nature of ACS implies a requirement for jointness with other DoD agencies. The development of air inflatable shelters, alternative power generation systems and various force protection technologies are examples of the kinds of programs that all services need. Many programs share or receive information from the other DoD organizations such as DARPA, Army's Natick Lab, the OSD, and the Navy's Explosive Ordinance Disposal Technology Division.

AFRL ITTPs / Enabling Technology Areas	Deployed Base Support Systems	Deployment Planning, Command and Control, Reduced Airlift and Sustainment	Force Protection	Active Denial Technology (ADT)
Directed Energy				●
Information		○	○	
Sensors				○
Propulsion		○		
Air Vehicles				○
Human Effectiveness		●	○	○
Materials & Manufacturing	●	○	●	○

● = Lead ○ = Participating

Figure 4-6: Correlation of Agile Combat Support ITTPs to ETAs

4.5.5 Agile Combat Support ITT FY25 Vision

AFRL directorates recognize the challenges inherent in meeting the ACS ITT objectives and in response have developed specific technology goals. For conventional aerospace forces, their technologies will enable a force to respond in less than one-half the time currently needed, with less than one-third of the people deployed forward, and with 60 percent less support requirements. Their technologies will also allow for complete, real-time battle space awareness with in-route deployment planning. Communication systems will be developed to ensure all forms of in-transit visibility will allow for a streamlined process of resource tailoring. Increased engine reliability and maintainability, as well as embedded diagnostics systems, will facilitate more efficient methods of maintenance support. There will be anti-jam differential GPS and remote air traffic control capability that will enable enroute and deployed visibility of aircraft and the flexibility to change deployment location enroute. Ground distribution/movement systems will be improved to allow full in-transit visibility and rapid handling of support assets. The improved information infrastructure and global communications will allow access to US based expertise for both medical and maintenance diagnoses. Forces will be better protected as well through improvements to chemical and biological masks and detection systems. Increased efficiencies of both weapons and weapon delivery systems will further reduce the deployment footprint.

New technologies will enable full spectrum ACS from space assets with virtually no requirement for deployed maintenance on weapons delivery or support platforms. RLVs and a resupply capability via space plane will support an EAF. Endothermic fuels, lightweight materials and deformable optics will become the norm. Directed Energy technologies will be the mainstay for force protection activities. Space-based platforms will continue to enhance threat detection, target identification, terrain categorization and battle damage assessment. They will also increase the ability to provide real-time information both to and from the battlefield.

4.6 Training for Warfighting

"Provide A Capability to Train the Way We Fight Through A Distributed Warfighting and Decision-Making Environment"

The Air Force is moving toward a more Expeditionary Aerospace Force (EAF) to deal with 21st century contingency operations. The new EAF organizationally links forces of geographically separated units into standing air expeditionary forces. The EAF is built on the principle of being "light, lean and lethal" as stated by the Air Force Chief of Staff (CSAF). To ensure that this new expeditionary aerospace force can deploy (light), create decisive effects (lethal), and accomplish the mission effectively with minimum resources (lean), the warfighters must be properly trained. The training must be both complete and realistic. Succinctly, the Air Force must train the way it intends to fight.

Training will play a vital role in preparing the individual units to function as part of the EAF team. Training these teams for every contingency is impractical and unachievable using today's training paradigm. The solution to training team roles and coordinated activities among geographically separated units is through universal and rigorous use of Distributed Mission Training (DMT). This training mixes live (real people in real systems and environments), virtual (real people in simulated systems and environments) and constructive (computer-generated representations of people and systems in simulated environments) elements.

4.6.1 Training for Warfighting ITT Planning Context

Joint Vision 2010 provides the conceptual template for American forces to achieve new levels of effectiveness in joint warfighting. This vision embodies four operational concepts: Dominant Maneuver, Precision Engagement, Focused Logistics and Full-dimensional Protection. Of crucial importance to all four operational concepts are high quality, highly trained forces. *Joint Vision 2010* requires that operations are planned knowing the men and women of the military have the skills and character to execute their tasks successfully and that readiness is maintained through realistic and stressful training. *Joint Vision 2010* calls for joint education and training which prepares joint warriors to meet the challenges of the future battlespace. It also calls for enhanced modeling and simulation of the battlespace, interconnected globally to improve the realism of training. The global simulation network will create an interactive simulation superhighway connecting geographically dispersed units, including the guard and reserve, for joint training and exercises.

In early 1996, General Ronald Fogleman, then CSAF, called upon the Air Force to "revolutionize" training through the use of modeling and simulation. General Michael Ryan, current CSAF, continued this direction in his 1998 Posture Statement. He said, "We are also pursuing the development of revolutionary new ways to train our operational air crews. Distributed mission training will use state-of-the-art distributed simulation technology and advanced flight simulators to permit air crew to remain at their home units while 'flying' and training in synthetic battlespace, hooked electronically to other air crews located at distant air bases. This will improve the quality and availability of training while reducing aircraft operation and maintenance costs, as well as limiting the amount of time our personnel will have to spend away from home."

4.6.2 Training for Warfighting ITT Investment Strategy

Training for Warfighting ITTPs

- Warfighting Operations Center Training
- Simulation and Distributed Mission Training

Developing a robust and realistic training environment is based on the premise that training is the peacetime manifestation of war. The training for Warfighting ITT's investment strategy is to apply DMT methods and technologies to network real, simulation and computer generated weapon systems and information assets, enabling multiple trainees at multiple sites to engage in complex, scaleable and tailorable synthetic training environments which mirror the modern battlefield. DMT enables training, individually or collectively, at all levels of contingencies or war. Individual units and joint forces can participate in training exercises in a Joint Synthetic Battlespace while operating from their own location. Distributed interactive simulation enables more training opportunities, a greater variety of training, and less deployment for training. This also results in less dependence on aircraft as the only realistic media for providing air crew training, increases safety and reduces flying hours used for training, thus, reducing airframe fatigue rates.

This integrating thrust will encompass the full spectrum of training events and environments both sequential - planning, execution, and debrief - and functional - air crew, command and control, support and protection. The primary long-term goal of this ITT is to provide warfighting decision-making training and operational decision-making support by merging operations and training into common, seamless, global aerospace power structure. The initial two ITTPs are: Warfighting Operations Center Training and Simulation and Distributed Mission Training. Technical objectives and a brief description for each ITTP follow:

Warfighting Operations Center Training

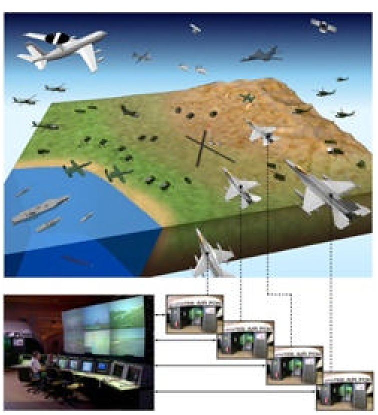
Objective: Improved information handling and decision-making training

Training for Warfighting

Warfighting Operations Center Training supports training from the Joint Forces Air Component Commander (JFACC) through the wing and down to the squadron level through a seamless, integrated information system. The goals of this effort are to see how information is acquired, manipulated, processed, stored and used to make decisions from the JFACC to unit level, in preparing for combat and training missions and in reviewing mission execution. This seamless manipulation of data will translate into more effective and efficient training and operations. The integration of mission planning, automated brief/debrief, simulation, weapon systems and Command, Control and Intelligence (C2I) systems will provide expanded access to common information to dramatically improve decision making, training and warfighting.

Simulation and Distributed Mission Training

Objective: Affordable, realistic warfighter training with reduced reliance on weapons systems for training



Networking Training Assets

DMT is the networking of training assets including live, simulated and computer-generated forces to allow multiple players at multiple sites to engage in complex, scaleable, synthetic training environments. Using the capabilities and technologies demonstrated through the AFRL Warfighter Training Division's integrated DMT testbed, these enhanced technologies will provide realistic combat environments without the expense and time exhausted on current ranges and exercises. DMT will enhance debrief, data collection, analyses and replay of missions to enable mission replanning and retargeting, combat assessment, and final execution.

4.6.3 FYDP Investment Strategy for Training for Warfighting ITT

Table 4-8 summarizes the present ITTPs, the technologies being developed, and the payoffs in terms of improved operational capability to be realized upon completion.

Training for Warfighting ITTPs	Technologies Being Developed	Payoff
Warfighting Operations Center Training	• Information technology Information management tools and methods; data fusion; data compatibility; database technologies and techniques; data model management • Representation technology Synthetic environments; simulation development environments; human, group, vehicle and threat behavior models • Instructional technology Training methods; training effectiveness assessment; simulator-to-aircraft skill transfer; human behavior/cognitive processes • Interconnection technology Communications networks; distributed simulation networks; simulation/comm protocols; modeling and simulation; multi-level security • Pervasive technologies Computer processing; visual displays; image generation; data storage and retrieval; high-speed, high-volume comm lines	• Realistic integrated EAF battlestaff training methods, criteria and curriculums • Realistic training and rehearsal environments for geographically separated units • Advanced DMT control/instructor station • Fast, flexible, scaleable data management for intelligence data • Theater-level distributed network nodes for full team interaction
Simulation and Distributed Mission Training (DMT)		• Improved joint training networks • Effectiveness measurements for "fly vs simulate" decision criteria • Affordable, realistic, on-demand training • Reduce training system acquisition/sustainment costs 30% • Reduce in-flight training hours 30% by reducing dependence on weapon systems for training • Reduce time in training pipelines by 40% • More realistic human, group, vehicle, and threat behavior models and realistic electromagnetic, optical and infrared threats • Simulation training methodologies and effectiveness metrics for individuals and teams • Human behavior/cognitive processes models for improved visual displays/image generation systems • High performance data storage and retrieval to enable photo-fidelity realism and physics-based interaction • High-speed/bandwidth communication lines capable of handling high-fidelity Simulation Object Model (SOM) data packets for hundreds of high-dynamic vehicles

Table 4-8: Summary of Training For Warfighting ITTPs

4.6.4 Relationship of Other S&T Programs to Training for Warfighting ITT

The foundations for the two "Training for Warfighting ITTPs" are enabling technologies developed in the ETAs. Figure 4-7 shows the ETAs that will provide the components for the individual ITTPs.

Training for Warfighting also supports the *Joint Warfighting Science and Technology Plan* (JWS&TP). Paramount among the DTOs in the JWS&TP is the Synthetic Theater of War (STOW). STOW is providing operational demonstrations of advanced distributed simulation technologies that directly support joint

Enabling Technology Areas \ AFRL ITTPs	Warfighting Operations Center Training	Simulation and Distributed Mission Training
Space Vehicles	❍	❍
Directed Energy	❍	❍
Information	❍	❍
Sensors	❍	❍
Human Effectiveness	●	●

● = Lead ❍ = Participating

Figure 4-7: Correlation of AFRL's Training for Warfighting ITTPs to ETAs training and mission rehearsal. The current and future Training for Warfighting ITT technologies plays a key role in this DTO. The future capabilities of technologies generated by this ITT could satisfy the needs of many of the 10 JWCOs. Current ITT programs address the needs of Joint Readiness and Logistics and Sustainment of Strategic Systems.

4.6.5 Training for Warfighting ITT FY25 Vision

By 2025, the technologies developed under the Training for Warfighting ITT will provide distributed mission training for all Air Force weapon systems and missions including integrated training for C2 systems, battlestaffs, joint force commanders, air operations centers, and space force assets.

These teams and assets will be linked in distributed simulation networks serving both information and training needs. In this environment, training methods can also be expanded to encompass team and organizational behavior models. Training methods can be further expanded to encompass robust battlestaff, intelligence, planning, and operations centers team training for geographically dispersed units. With this expanded training approach, the Air Force can train for all levels of the mission and can conduct comprehensive mission rehearsals by simulation and support mission planning, execution and debrief. Automated planning assistants and post mission assessment tools can be developed which will lead to rapid (24-hour) simulation of combat theater order of battle. A light, flexible, reliable deployment capability will be developed to support training and operations of deployed units.

This ITT will reduce separate stand-alone simulations by 80 to 90 percent and provide transparent multi-level security for all training systems and scenarios. The applied human systems interface expertise will adapt training systems to fit individual human potential resulting in a 40 percent reduction in training time.

5.0 Enabling Technology Areas

Enabling Technology Area (ETA) programs provide technology options for improved warfighting capability and include options for performance, sustainment, and affordability improvements. Some of the enabling technologies are single-discipline technology efforts and may transition directly to Air Force systems. Other enabling technologies are the components for ITTPs. Whereas sector offices manage ITTPs across AFRL, the enabling technologies are managed by the technology directorates. Planning for these enabling technologies is by ETAs identified below.

Air Force S&T ETAs

Space Vehicles	Sensors	Air Vehicles
Directed Energy	Munitions	Human Effectiveness
Information	Propulsion	Materials and Manufacturing

Within each ETA there are technical thrusts. A listing of the ETAs with their associated technical thrusts is presented in Table 5-1.

Space Vehicles ETA (Section 5.1) Space-Based Surveillance Space Capability Protection	Directed Energy ETA (Section 5.2) Advanced Optics and Imaging Laser Technology High Power Microwave	Information ETA (Section 5.3) Global Awareness Dynamic Planning & Execution Global Information Exchange
Sensors ETA (Section 5.4) Radio Frequency (RF) Sensors & Countermeasures Electro-Optical (EO) Sensors & Countermeasures Automatic Target Recognition & Sensor Fusion	Munitions ETA (Section 5.5) Antimateriel Munitions Hard Target Smart Munitions Miniaturized Munitions Air Superiority Missiles	Propulsion ETA (Section 5.6) Air Propulsion Power Technology Aerospace Propulsion Space Propulsion
Air Vehicles ETA (Section 5.7) Aeronautical Sciences Structures Control Science	Human Effectiveness ETA (Section 5.8) Crew System Interface Warfighter Training Bioeffects and Protection Deployment & Sustainment	Materials and Manufacturing ETA (Section 5.9) Materials and Processes for Structures, Propulsion, and Subsystems Survivability & Sensor Materials Materials and Processing Technology for Sustainment

Table 5-1: Air Force S&T Technical Thrusts by ETA

5.1 Space Vehicles

"Technologies to Enable Space Supremacy"

The vision of the Space Vehicles ETA is to develop innovative space technologies that make warfighter missions more effective and affordable. Rapid and cost-effective research, development and transition of advanced space technologies enables affordable and decisive capabilities for U.S. forces. The Space Vehicles ETA is developing technologies that will provide the warfighter with options that take maximum advantage of space as an operating environment. The situational awareness afforded throughout the battlespace − on the surface of the earth, in the air, and in space − provides the means for aerospace supremacy, enabling the full range of options for other weapons systems employed in theater. This provides the nation not only a precision global strike capability with minimum casualties and collateral damage, but also the possibility of strategic deterrence, flexible responses, and the ability to influence events in real-time. Investment in these capabilities will provide the warfighter with a continuous range of response options, varying from lethal to non-lethal.

5.1.1 The Planning Context for Space Vehicles Technology ETA

Global Engagement, as envisioned by the Air Force, requires information superiority. Information superiority relies heavily upon space capabilities to collect, process, and disseminate an uninterrupted flow of information while denying an adversary the ability to do the same. Space forces also play an increasingly critical role in providing situational awareness to U.S. forces (global communications, precise navigation, timely and accurate missile warning, weather, intelligence, surveillance, and reconnaissance). As space systems become more critical to U.S. military operations, they are more likely to be attacked by adversaries. There will be a critical need to control the medium of space to ensure U.S. dominance on future battlefields. Robust capabilities to ensure space superiority must be developed − just as they have been for land, sea, and air.

To support *Joint Vision 2010*, the Air Force's vision of Global Engagement and the Air Force Strategic Plan, the Air Force Space Command (AFSPC) has adopted four operational concepts. These concepts, which provide a framework for developing space superiority capabilities, are Control of Space, Global Engagement, Full Force Integration, and Global Partnerships. Control of Space requires real-time surveillance of space, assured access to space through timely and responsive spacelift and satellite operations, enhanced active and passive protection capabilities for military and commercial satellites, and robust negation systems. Global Engagement requirements include non-intrusive global surveillance and enhanced precision strike capabilities through space systems and limited space-based strike weapons. Full Force Integration capabilities include enhanced sensor-to-shooter capability, common protocols and fused databases, along with precise modeling and simulation. Global Partnerships augment military space capabilities through leveraging civil, commercial and international space systems.

5.1.2 Investment Strategy for Space Vehicles ETA

The Space Vehicles ETA's investment strategy is to enable space superiority through innovative application and evolutionary growth of current technologies as well as development of revolutionary technologies. This ETA will pursue technologies driven by specific military operational needs. These include technologies to maintain near perfect knowledge of the enemy and communicate that to all forces in near real-time, to engage regional forces promptly in decisive combat on a global basis, and to employ a range of capabilities to achieve military objectives with minimum casualties and collateral damage. Technologies to ensure the Control of Space and the ability to counter threats to the United States and deployed forces will be developed.

5.1.3 FYDP Investment Strategy for Space Vehicles ETA

Space Vehicles ETA Thrusts
- Space-Based Surveillance
- Space Capability Protection

The Space Vehicles ETA develops technologies across the spectrum from near-term to far-term. The Space Vehicles ETA invests funding in near-term activities primarily focused at the sub-system and demonstration level and in mid-term exploratory development activities to provide evolutionary technologies at the system level. The investment strategy for the Space Vehicles ETA emphasizes improved productivity at reduced cost. The need for affordability is a pervasive requirement emphasized throughout all aspects of the Space Vehicles ETA. Maximum leverage of these S&T investments is accomplished through the broad base of this ETA to support many Air Force mission areas.

The overarching vision of space superiority is implemented through two major technology thrusts that provide focus and direction to the technology investment plans. These technology thrusts are Space-Based Surveillance and Space Capability Protection.

Space-Based Surveillance

MightySatI Satellite Demonstrates Space Technologies

Space-Based Surveillance Subthrusts
- All Weather, Day/Night Surveillance
- Detection and Characterization of Difficult Targets
- Long Dwell/Continuous Global Coverage

The Space-Based Surveillance thrust provides focus and direction to active and passive surveillance technology investments that assure innovative and revolutionary techniques for detecting and determining threats. These investments form the foundation for the tactical situational awareness of the 21st Century.

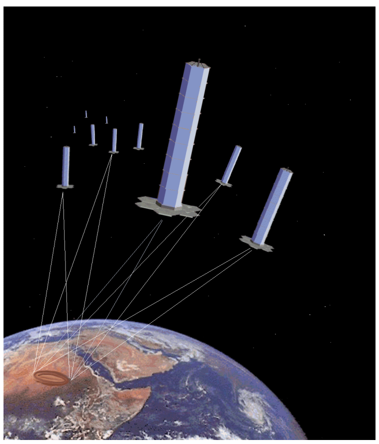
Classical, wide-area surveillance will continue to be a critical Air Force mission area, but this thrust will specifically address advanced technologies for tactical theater area interrogation and high value targeting that will be used for cueing other sensor and weapons systems. A critical part of theater information will be the knowledge of the battlespace environment. Revolutionary remote sensing tools will allow a level of situational awareness on the ground, in the air, and in space that has never before been available to the warfighter. To achieve this goal, techniques (including sensors and operational models) will be developed to specify and forecast the battlespace environment and its effects on Air Force systems and operations. This thrust will provide the capability to observe, model, and predict environmental conditions encountered by the warfighter at anytime, anywhere on the globe.

This thrust provides a common technology base from which surveillance systems for space platforms can be developed with confidence. Technologies developed will provide capabilities for near real-time surveillance of space to characterize potential targets; real-time bomb damage assessment; near real-time, highly accurate, integrated, focused surveillance systems; and robust, integrated intelligence (surveillance and reconnaissance, command, control, communications, precision navigation, position, timing data and weather). This encompasses a wide range of disciplines including structures and controls, thermal management, and electrical power systems.

The Space-Based Surveillance thrust is divided into three subthrusts. The All Weather, Day/Night Surveillance subthrust develops space-based radar technologies (antennas, data exploitation, ionospheric effects, collaborating constellations), spacecraft energy generation (solar cells, advanced concepts) and storage (batteries, flywheels) and improved space computing capability. The Detection and Characterization of Difficult Targets subthrust develops hyperspectral and multi-color sensors, data fusion, exploitation and dissemination, as well as techniques to mitigate sensor background effects. The Long Dwell/Continuous Global Coverage subthrust develops lightweight optics, precision structural controls, multi-functional structures and autonomous systems, as well as technologies applicable to the microsat class of satellites. The Space-Based Surveillance thrust will achieve the following near-term payoffs:

- Increase probability of ballistic missile launch detection to at least 90 percent under all weather conditions
- Improve Air Force space electronics system capability by at least a factor of ten
- Reduce cost to develop and test systems by 50 percent through new computer architectures and standards
- Space-based optics with ten times the area of the Hubble telescope, with one quarter the mass, at a production rate ten times as fast and one-tenth the cost per square meter of Hubble
- Factor of four reduction in vibration transmitted from spacecraft components to primary structure
- Factor of seven increase in solar array power per area
- Reduce satellite structure weight of large (1,000 lb) satellites by 20 percent
- Increase solar cell SOTA efficiency from today's 21 percent to 35 percent
- Reduce conventional planar solar array mass by 65 percent for constant power level
- Reduce satellite bus part count 75 percent through use of multi-functional structures
- Decrease the cost, mass, and volume of satellite energy storage systems by at least 50 percent
- Increase momentum storage capability 50 to 100 percent for satellite attitude control actuators using flywheels in place of reaction wheels and control moment gyros

Space Capability Protection



TechSat 21 Effort Will Employ Clusters of Microsatellites

Space Capability Protection Subthrusts

- Hazard Alerts / Prediction
- Passive Protection
- Active Protection

Control and exploitation of space is an Air Force mission. The Space Capability Protection thrust provides focus and direction to technology investments that assure the survival of our space systems, whether the threat is natural or man-made. This thrust is broadly defined to address everything from radiation hardened electronics to threat warning and attack reporting. It includes both passive and active techniques for self-protection as well as the development of protocols for debris management and mitigation. A major objective of this thrust is to advance the understanding of the effects of interactions between the environment and military systems and provide guidance to designers of advanced systems to ensure increased survivability and reduced weight and cost. Satellite autonomous operation will usher in a new era of information-on-demand satellite systems, with interconnected constellations of satellites providing precisely the information that the warfighter needs. Mobility in space, coupled with less expensive and easier access to space, is key to Air Force dominance of the space arena. Decision aids must be developed for mission planning and operations that predict the expected performance of military systems based on anticipated conditions in the environment. The Air Force of the 21st Century will have to move in and through space with the same ease it now moves in and through the air. Orbit transfer propulsion systems will be key to this essential capability. Deploying these capabilities in space will be made more affordable through investments in lighter and higher performance lift systems; improvements in design, integration and operation processes; component weight reduction; and operation and control technologies.

The Space Capability Protection thrust focuses on protecting DoD space capabilities against the full range of natural and man-made threats. The thrust includes projects to determine atmospheric properties affecting the propagation of laser weapons; laser-based communications; chemical, biological, and nuclear weapons; and air delivery of munitions, supplies and troops. The thrust will develop advanced technologies in launch vehicle structures and in active and passive satellite threat warning/mitigation as well as advanced radiation-hardened spacecraft electronics for both military and commercial applications.

This thrust is divided into three subthrusts: Hazard Alerts/Prediction, Passive Protection and Active Protection. The Hazard Alerts/Prediction subthrust develops technologies to monitor, specify and predict the natural spacecraft environment and develop miniaturized on-board hazard detection systems. The Passive Protection subthrust develops technologies and techniques for hardening spacecraft structures, electronics, and electro-optical subsystems. The Active Protection subthrust develops technologies for active control and negation of natural and man-made threats as well as advanced technologies for on-orbit maneuverability. The Space Capability Protection Thrust will achieve the following payoffs:

- Reduce errors in atmospheric drag predictions required by AFSPC for satellite tracking, collision avoidance, and re-entry predictions to five percent
- Reduce errors in global ionospheric specification and forecast to ten percent or less
- Increase targets killed per sortie by over 15 percent through improved weather decision aids
- Assure communications and GPS navigation for hypersonic systems such as the SOV, common aero vehicle, and conventional ballistic missiles
- Reduce weather aborts over target by 50 percent
- Improve mission success rate for airborne laser theater missile defense operations by 60 percent
- Reduce launch vehicle structural mass 20 percent through development of innovative structures
- Reduce launch vehicle structural subsystem cost by a factor of ten

5.1.4 Relationship of Other S&T Programs to Air Force Space Vehicles ETA

Within AFRL, this ETA provides enabling technologies to three of the six ITTs and to 15 ITTPs (Table 5-2). Projects in the Space-Based Surveillance Thrust directly support the Space Optics and Laser Technology, Hyperspectral Imaging, and Space-Based Radar ITTPs. Projects in the Space Capability Protection Thrust directly support the Space Operations Vehicle, Space System Survivability, Hyperspectral Imaging, and Space-Based Radar ITTPs.

Space Superiority ITT
• Space Operations Vehicle* • Space-Based Radar • Space Optics and Laser Technology • Hyperspectral Imaging* • Space System Survivability*
Precision Strike ITT
• Automatic Target Recognition • Real-Time Sensor-to-Shooter Operations • Sensor Protection
Information Dominance ITT
• Configurable Aerospace Command and Control • Defensive Information Warfare • Common Battlespace Picture • Global Grid • Dynamic Command and Control
Training for Warfighting ITT
• Warfighting Operations Center Training • Simulation and Distributed Mission Training
**Led By AFRL/VS*

Table 5-2: Space Vehicles ETA Relationship to ITTPs

Significant funding to the Space Vehicles ETA is provided by BMDO, DARPA, NASA, and others. Over the past few years, commercial space activity has grown to equal, and will soon exceed, the government's space activities. Thus, an emphasis is being placed on direct commercial exploitation, assessment of commercial-off-the-shelf (COTS) technology for military applications, and cooperative research and development with industry, academia and other space-focused government organizations. This situation is forcing a transformation of relations between government and industry in the space sector. In an effort to develop cooperative approaches to planning and investments for developing advanced space technologies, AFRL has led the creation of the Space Technology Alliance. Current government participants are the Air Force, Army, Navy, NASA, NRO, DARPA, BMDO, and the Department of Energy. Private industry participates through the Aerospace Industries Association.

AFRL has also led the creation of the Space Technology Institute (STI), a collaborative forum between United States academic institutions with strong space curricula/research programs and space vehicles enabling technologies. The STI will stimulate innovation in space technology programs and leverage on-going space technology research in academia.

5.1.5 Space Vehicles ETA FY25 Vision

The Space Vehicles ETA will continue to pursue innovative technologies and strategic partnerships leading to United States space superiority in the 21st Century. Lightweight solar arrays will combine advances in thin-film photovoltaics, smart mechanisms, and multifunctional structures to attain a two-to-three times improvement over state-of-the-art solar array specific power. Integration of electronics, sensors, power distribution and storage, and thermal management with modular, lightweight structures will enable a cable-free next generation spacecraft, with potential reductions of ten times the weight and over two times the volume compared to current state-of-the-art spacecraft. Combined with highly integrated packaging and processing concepts, flywheel energy storage, and advanced electric propulsion concepts, future spacecraft will be one-third the mass of current designs, at lower cost, with higher performance.

Revolutionary technologies such as these will enable a new class of highly capable microsatellites weighing between 10 and 100 kilograms. Current space missions will be performed with smaller, lighter, more cost-effective satellites. These technologies will enable new missions in satellite logistics and control as well as the tactical use of space. Constellations, or clusters of collaborating microsatellites, will provide inexpensive, reconfigurable, fault-tolerant and adaptable solutions to many new and current missions.

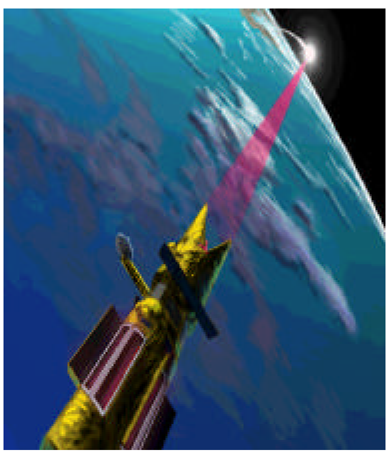
5.2 Directed Energy

"Revolutionary Warfighting and Protection Capabilities to Dominate the Battlespace of the 21st Century"

The Directed Energy (DE) ETA encompasses the development, demonstration and transition of DE technologies to the warfighter. This includes not only developing systems to exploit foreign system susceptibilities but also developing protection technologies to minimize the vulnerability of Air Force systems to similar foreign threats. The ultimate goal for the DE ETA is to provide dramatic new warfighting capabilities that will enable the Air Force to leap over the on-going evolutionary development process of conventional systems. The revolutionary improvement in flexibility, speed-of-light attack, and a "deep magazine" open the possibility of a host of new missions. This ETA includes not only developing systems to exploit foreign system susceptibilities but also developing protection technologies to minimize the vulnerability of Air Force systems to similar foreign threats.

The DE ETA's vision is to develop, integrate and transition directed energy technologies, including high power microwaves, lasers and adaptive optics to meet defense needs. This vision includes identifying mission effectiveness of potential directed energy technologies, support of user needs for directed energy applications, and the exploitation of directed energy technologies. Key to this vision is the ability to foster user awareness of directed energy's potential DoD applications and high payoffs.

5.2.1 The Planning Context for Directed Energy ETA


High Power Laser Program

Directed Energy technologies provide a revolutionary class of unique capabilities for the DoD. This includes advanced optics and imaging, high power lasers, and high power microwave technologies which will reshape the future of all military operations. They have the revolutionary advantage of speed-of-light delivery, long range, graduated effects, minimal collateral damage, and potentially low cost per kill. High power laser and high power microwave technologies have matured to the level that they can be brought to military demonstration and deployment. Major applications will include defense against antiaircraft missiles; boost phase defense against ballistic missiles; and disruption or destruction of C4I targets by airborne weapons and later by high altitude UAVs and space based or space relayed weapons. In mature form, space based or space relayed weapons will provide real time world wide terrestrial and space engagement capability, with revolutionary implications on the nature of warfare.

The DE ETA has been shown to be critical to the Air Force's long and short-term military needs as specified in the core competency descriptions. It employs a strategy that encompasses a full spectrum of basic research, exploratory development, and advanced development to meet near-term product milestones and long-term requirements for higher performance and lower costs. The Air Force is prepared to be the DoD single focal point for all DE R&D and AFRL/DE is prepared to be the Air Force's single focal point for DE R&D.

5.2.2 Investment Strategy for Directed Energy ETA

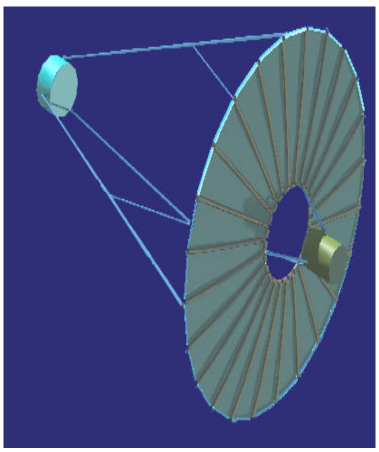
The investment strategy is to develop and demonstrate systems based on lasers, microwaves, optics and imaging. This ETA will also provide System Program Offices (SPOs) with the technology needed to reduce the threat to systems from the adverse use of directed energy weapons (DEWs). To accomplish this, the AFRL is assisting operational commands in understanding the current and future capabilities of DEWs and how DEWs can solve operational mission area deficiencies. Key to achieving these goals are critical elements being addressed regarding robustness, reliability, packaging, and cost.

5.2.3 FYDP Investment Strategy for Directed Energy ETA

> **Directed Energy ETA Thrusts**
> - Advanced Optics and Imaging
> - Lasers
> - High-Power Microwave

This ETA plays a particularly critical role for DoD because it provides many military unique applications. It employs a strategy that encompasses a full spectrum of basic research, exploratory development, and advanced development to meet near-term product milestones and long-term requirements for higher performance and lower costs. For the FYDP, AFRL will expand the S&T knowledge of laser and microwave sources, beam control, target acquisition and tracking, and target and atmospheric interactions. These technical disciplines are addressed within the DE ETA's three technical thrusts of Advanced Optics and Imaging, Lasers, and High-Power Microwave (HPM). Under each of these thrusts, AFRL will integrate and demonstrate DE system concepts to prove technical feasibility, reduce development risks and increase user interest and understanding. These demonstrations include the development and validation of M&S tools necessary to produce affordable directed energy systems.

Advanced Optics and Imaging Technology



Optics and Imaging

> **Advanced Optics and Imaging Technology Subthrusts**
> - Large Optics
> - Remote Sensing Technology
> - Space Surveillance Situational Awareness
> - Beam Control

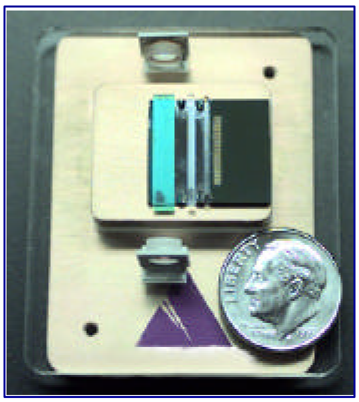
The overall objective of the Advanced Optics and Imaging thrust is to provide the world's best optics and imaging. The Advanced Optics and Imaging technology thrust has four subthrusts: Large Optics; Remote Sensing Technology; Space Situational Awareness; and Beam Control. These subthrusts take advantage of the adaptive optics and target acquisition tracking technology developed under the beam control subthrust to produce compensation stabilized images. Maturing laser source and beam control technology is also the foundation for a revolution in optical imaging. Atmospheric compensation and illumination laser technology, in combination with innovative image sensing and processing concepts, will greatly improve the coverage and resolution of imaging systems. This thrust also involves developing and transitioning multi-spectral sensing and image processing technologies for high resolution imaging applications; advanced electro-optical detection techniques for situational awareness; exploiting light detection and ranging (LIDAR) for long range, stand-off remote detection of information critical to the warfighters.

Specific military applications include high-energy lasers (HELs), high power pulsed lasers, and remote sensing of battlefield conditions and space environments. Large optics characterize and develop specialized systems, subsystems, components, and coatings for use in HEL systems. Remote sensing is primarily for the LIDAR technologies for standoff determination of nuclear, chemical, or biological agents under battlefield conditions. There is strong interest in environmental and industrial remote sensing applications, particularly in the counter proliferation arena. The Air Force holds a significant lead in developing these technologies. The development of lightweight space optics is critical to the advancement of lasers in space. The Space Vehicles ETA and the Jet Propulsion Laboratory are both examining optics technology for radar or radio frequency applications. This ETA is developing unique approaches to compensate for optical aberrations in high-energy laser systems. Space surveillance is critical for Space Command military space order of battle and space control, in particular for large satellite constellations. Industry needs and uses products and capabilities from space surveillance daily. This is a growing area of interest for industry and Space Command. Beam control develops and demonstrates critical optical acquisition, tracking, and pointing technologies for HEL system stabilization and pointing and for image place stabilization for optical imaging applications.

The Lasers in Space (LASSOS) study demonstrated a need for an optical relay mirror system in space. This ETA is forming the foundation for an integrated, intra-technology directorate, technology development and demonstration program for large, lightweight space optical systems including relay mirrors. The Advanced Optics and Imaging technology thrust will achieve the following near-term technology payoffs:

- Create a Ground-Based Laser (GBL) technology readiness demonstration
- Increase Airborne Laser (ABL) range to 1.5 times
- Develop a capability to detect and identify, at long stand off ranges, chemical weapons in production or use on the battlefield
- Develop advanced GBL beam control technologies for use at the Advanced Electro-Optical Sensor (AEOS) and Starfire Optical Range (SOR)
- Develop technologies to image or sense GEO satellites
- Automatically remove the effects of atmospheric and large optic figure errors on laser beams and imaging systems

Laser Technology



Laser Integration Technology

This thrust is developing, integrating and transitioning laser and nonlinear optical systems for the warfighter. The objective is to establish the feasibility and payoff of lasers in advanced weapons, communication, battlefield illumination and target designation, remote sensing, theater and global wind measurements, camouflage detection/ penetration and optical countermeasure applications. Lasers under investigation include semi-conductor, gas, chemical and solid-state. This thrust is developing laser technologies for the ABL and GBL programs.

Laser Technology Subthrusts

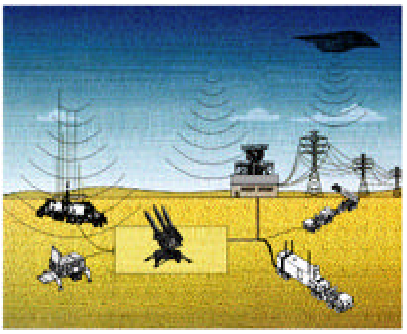
- Near-Infrared Semiconductor Laser Technologies
- Mid-Infrared Semiconductor Laser Technologies
- High Power Gas and Chemical Laser Technologies
- Laser Integration Technology
- Disrupt and Degrade Infrared Countermeasures

The Lasers technology thrust is divided into five subthrusts: Near-Infrared (IR) Semiconductor Laser Technologies, Mid-IR Semiconductor Laser Technologies, High Power Gas and Chemical Laser Technologies, Laser Integration Technology (LITE) and Disrupt and Degrade (D2) Infrared Countermeasures (IRCM). The Near-IR Semiconductor Laser technologies subthrust is developing and demonstrating semiconductor diode laser and diode laser arrays for aircraft self-protection, laser communications and laser radar for precision guidance munitions. The Mid-IR Semiconductor Laser technologies subthrust is developing and demonstrating high power mid-IR (2-5 micron) semiconductor laser/array technologies for aircraft self-protection, illumination, chemical agent detection, IR missile warning sensor jamming and laser array pumping modules. The High Power Gas and Chemical Laser technologies subthrust is developing and demonstrating high power gas and chemical laser technology needed for ABL technology insertion, and GBL anti-satellite (ASAT) and SBL weapon applications. The LITE subthrust is developing dual-clad fibers, high-power connectors, fiber lasers and fiber laser arrays, micro-bench methods of implementation, integrated optics, scaleable pump modules and beam combining technologies. The D2 IRCM subthrust is developing laser technology for IRCM source, focal plane arrays (FPAs) susceptibility testing, countermeasure effectiveness evaluation, imaging missile surrogate fabrication, missile seeker damage testing and an advanced pointer/tracker. The Lasers technology thrust will achieve the following near-term technology payoffs:

- Create a single semiconductor to obtain devices with up to ten watt continuous output and good beam quality
- Demonstrate mid-IR sources using cascaded parametric processes
- Produce high power illuminators for laser systems and missions
- Meet remote sensing and countermeasure requirements
- Develop specialized optical components/coatings for use in high energy laser systems, emphasizing low absorption, low scatter, high reliability and environmental stability
- Create the ability to operate from near-ultraviolet thru the visible to the near-infrared wavelength region

- Create an advanced, high brightness near- and mid-IR semiconductor laser device with a coherent diode laser array architecture leading to a prototype laser system developed for rapid applications
- Develop and demonstrate laser integration technology of modular/scalable, high efficiency fiber optic lasers for aircraft self-protection IRCM and DEW applications
- Develop Band I and Band IV semiconductor laser subsystems
- Develop countermeasures against the threat of advanced IR-guided, surface-to-air and air-to-air

High Power Microwave Technology



High Power Microwave Applications

High Power Microwave Technology Subthrusts

- Suppression of Enemy Air Defenses
- Command and Control Warfare
- Active Denial Technology
- Advanced Tactical Applications Technology

HPM represents a major advance in electronic warfare technology by extending a conventional RF power output several orders of magnitude. This thrust is developing and transitioning HPM to support source, antenna and pulse power requirements for major application programs. It will develop and transition RF hardening techniques to Air Force product centers and industry and seek out new applications for HPM.

The HPM Technology thrust has four subthrusts: Suppression of Enemy Air Defenses (SEAD), Command and Control Warfare, Active Denial, and Advanced Tactical Applications. The SEAD subthrust will demonstrate pulse power and microwave sources, mission effectiveness and capabilities associated with SEAD technologies. The Command and Control Warfare subthrust is addressing application development, effects experiments, source parameter definition, analysis of effects data, selective engagement concept development, source design and development, high illumination effectiveness and pulsed power device effects. The Active Denial subthrust is addressing phenomenology, systems concepts and man-portable systems leading to vehicle mounted demonstrations. The overall objective for this thrust is to develop and transition HPM technology into the Air Force operational inventory and to protect U.S. systems against potential RF threats. HPM technology thrust will achieve the following technology payoffs:

- Develop, demonstrate, and transition HPM technology to disrupt, degrade, and destroy electronic components of an adversary's integrated air defense system
- Render inoperative, command and control capabilities through disruption and damage
- Develop, demonstrate and transition active denial technologies to users
- Develop pulse power and microwave sources

5.2.4 Relationship of Other S&T to Directed Energy ETA

Space Superiority ITT
• Space Optics and Laser Technology* • Hyperspectral Imaging • Space System Survivability
Precision Strike ITT
• Electro-Optical Countermeasure/ Infrared Countermeasure
Agile Combat Support ITT
• Active Denial Technology*
**Led By AFRL/DE*

Table 5-3: Directed Energy ETA Relationship to ITTPs

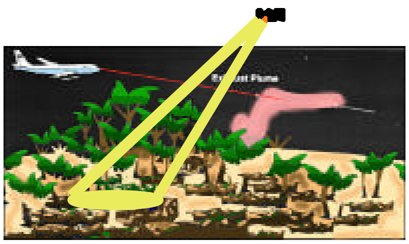
The correlation between the DE ETA and its ITT is shown in Table 5-3. This ETA provides enabling technologies to three of the six ITTs and five ITTPs. The Air Force is prepared to be the DoD single focal point for all DE S&T.

The AF holds a significant lead over the other military services in developing enabling LIDAR technologies and techniques and DE plays a critical role through Advanced Optics and Imaging. DE also has unique capabilities in image aberration compensation; handling high power lasers using AO methods; maturing laser sources; and beam control for a revolution in optical imaging technology. The NASA Jet Propulsion Laboratory and the AFRL jointly perform research on lightweight space systems for laser, radar or RF applications.

The Air Force has the only laboratory in the DoD with the resources, personnel and funding to provide a viable capability in laser R&D for military applications. In addition to developing laser technologies for ABL and GBL technology programs and consulting on the SBL Readiness Demonstrator, AFRL has consulted with the Army on the Theater High-Energy Laser program.

The Air Force has most of the DoD funding in HPM and much of the HPM expertise resides at AFRL. While the Air Force is primarily interested in HPM peak power, commercial industry is interested in average power. This difference comes from the requirements to use DoD systems for negation of enemy assets, while commercial organizations are using HPM for different purposes. Demonstrations and M&S tools will provide the foundation to spin-off technical information to civilian programs to further national interests.

5.2.5 Directed Energy ETA FY25 Vision



Enhanced Battlefield Awareness

From operational concepts of Precision Engagement, Full-Dimensional Protection and Dominant Maneuver, requirements have been identified for directed energy optics, imaging, high power microwaves, and lasers. Future DE operational capabilities will impact awareness, protection, graduated deterrence and precision strike. DE tools capable of detection and identification will greatly enhance battlefield awareness. High value military assets will be protected with invisible shields of DE. U.S. warfighters will have systems that provide a wide range of graduated force and the ability to strike deep into enemy territory at the speed of light, with little or no collateral damage.

Directed energy systems will provide revolutionary capabilities, such as transmitting disinformation through the enemy's communications links, immediate advanced weather mapping; instantaneous data gathering from satellites, isolating enemy populations from communications and information, neutralizing enemy space assets, and negating enemy missile strikes or launches. Specific system capabilities to be developed include an HPM UCAV prototype for SEAD; large, deployable, lightweight space optics and high power relay space mirrors for DEWs; robust laser IRCM for advanced threats; agile, robust lightweight DEWs of low to high powers; and tactical directed energy systems for combat aircraft.

5.3 Information

"Information Dominance for Space and Air Superiority"

The Information ETA develops Air Force unique information technologies for aerospace command and control using commercial practices and it transitions them to Air Force space, air, and ground systems for Global Awareness, Dynamic Planning and Execution, and Global Information Exchange. Areas of investigation for this ETA include fusion, communication, collaboration environments, distributed information infrastructures, modeling and simulation, defensive information warfare, and intelligent information systems and databases. Successful outcomes from these areas will provide affordable technology options required for Air Force Information Dominance and Aerospace Superiority. This ETA is committed to Information Dominance supporting Global Awareness by moving the relevant information through the Global Information Exchange environment that is predominantly commercial-based for the dynamic planning and execution of the battle plan.

5.3.1 The Planning Context for Information ETA

According to the Under Secretary of Defense for Research and Engineering, information technology is one of the top four priorities for DoD S&T. It impacts the vast majority of current and future Air Force systems.

Joint Vision 2010 emphasizes the need for information superiority - the ability to collect, process, and disseminate information while denying an adversary a similar ability. The high leverage of information technology and modern systems translates into significant improvements designed to improve the decision maker's ability to recognize, prioritize, assign, and assess information in a timely manner. Fusion of all-source intelligence with the fluid integration of sensors, platforms, command organizations, and logistic support centers will allow more expedient accomplishment of increased operational tasks.

Currently fielded command, control, communication and intelligence (C3I) systems do not support the timeliness, accuracy and relevance of information needed to meet the future joint warfighting needs as envisioned in *Joint Vision 2010* and Global Engagement. Information technology holds the key for battlefield management of the future. Situational awareness of who the enemy is, real-time knowledge of what is happening, and exploiting techniques associated with information warfare will be the critical functions.

5.3.2 Investment Strategy for Information ETA

The investment strategies defined by this ETA support *Joint Vision 2010*, the 10 JWCOs of the JWS&TP, and Service/Agency visions and requirements. Information superiority will allow warfighters to dominate and control the battlespace. This control is essential to virtually all joint warfighting capabilities in the 21st Century.

Strategic investment priorities must address warfighters' stated needs. Four generic considerations have high priority in making decisions about which specific technologies are pursued: affordability, dual use, accelerated transition, and a strong technology base. Diminished resources require greater emphasis on affordability throughout the S&T program. Dual use aspects of the program will contribute to building a common industrial base by using commercial practices, processes, and products and by developing, where possible, technology that can be the base for both military and commercial products and applications. However, to maintain our technological superiority, DoD must still field new state-of-the-art systems, at the rapid pace set by Air Force requirements.

The following capabilities are being developed to support the warfighter: acquire, store, distribute and protect information; quickly assimilate raw data for rapid ascension from data to knowledge to effective decisions; collaboration of real-time decisions across the force; assess, choose and rehearse courses of action; monitor execution results; and adjust plans, processes and resources to accommodate the dynamic battlespace environment. Technology efforts within the Information ETA are responsive to Air Force S&T and the unified DoD S&T investment strategy and are reported under the Project Reliance Information Systems Technology Panel.

5.3.3 FYDP Investment Strategy for Information ETA

To provide these capabilities the Information ETA has three thrusts: Global Awareness, Dynamic Planning and Execution, and Global Information Exchange. Descriptions of each thrust as well as those deficiencies currently being addressed are itemized as follows:

Information Technology ETA Thrusts

- Global Awareness
- Dynamic Planning and Execution
- Global Information Exchange

Global Awareness

Global Awareness Subthrusts

- Information Exploitation
- Information Fusion
- Global Information Base

Global Awareness provides a single, integrated battlespace picture on demand to support operations. The thrust has three subthrusts: Information Exploitation, Information Fusion, and Global Information Base. Information Exploitation is a set of processes that interpret and extract information from a time history of data. It registers the information in both time and geographical reference and stores the results in an easily accessed form in the Global Information Base. Information Fusion will correlate and analyze events, activities and movements, as they occur in time and space, for determining location, identity and status of individual objects (equipment and units). This correlation also determines threats to coalition operations and detects patterns for activities that reveal intent or capability. Global Information Base (GIB) is a distributed, heterogeneous data/information management system which stores awareness information and provides information services to dynamic planning and execution operations. Global Awareness goals include increasing the amount of data exploited, information fusion, with scalable resolution and accuracy, and storage /processing of information on platforms. Payoffs include:

- Timely, high confidence information, for the warfighters, to determine potential targets as friend, foe, or neutral and support weapons release and engagement decisions
- Providing the warfighter with intelligent agents that update knowledge bases with minimum human intervention
- Improving ATR based on audio acoustics (background noise)
- Improving information efficiently and effectively to operators and decision-makers
- Providing storage and retrieval nodes with access services to provide the warfighter the most current battlespace knowledge
- Developing an information baseline consisting of integrated, fused, accurate, real-time, and consistent data that can be accessed, analyzed, visualized, and transformed into relevant database
- Giving decision-makers the ability to make better informed, accurate, dynamic decisions through access of data representing the consistent battlespace picture

Dynamic Planning and Execution

Dynamic Planning and Execution Subthrusts

- Next Generation Command & Control
- Collaboration/Simulation/Visualization Technologies
- Aerospace Integration

Dynamic Planning and Execution describes the future operational capability to acquire and exploit superior, consistent knowledge of the battlespace. To accommodate the full scale of Air Force missions, dynamic planning and execution capabilities will be scaleable to minimize the deployment footprint. This will be accomplished by a worldwide distributed decision-making infrastructure of virtual battlestaffs and intelligence information specialists.

The Dynamic Planning/Execution thrust has three subthrusts: Next Generation C2, Collaboration/ Simulation/Visualization Technologies, and Aerospace Integration. The next Generation C2 program focuses on enabling a two orders of magnitude improvement in the agility, accuracy, timeliness, and efficiency over current command and control processes and structures. The technology will permit unprecedented opportunities for future aerospace battlestaffs to shape and control the pace and phasing of engagements. Collaboration/Simulation/Visualization Technologies will provide planners and decision-makers with the ability to view, understand and analyze the vast amounts of information available from C4ISR systems. Collaborating teams require a common, shared-context data environment, where the visualization of the data is tailored to the application domain and the user preference. Specific M&S capabilities will assist in both proactive and reactive assessment. Aerospace Integration recognizes that the information system environment, in order to support future C4ISR operations, can no longer be limited to ground-based centers for the support of air operations. Aerospace Integration extends the current C4ISR information architecture to include sensor to decision-maker to shooter concepts, the integration of space assets, and the incorporation of airborne-C2 into a seamless aerospace information environment. The Dynamic Planning and Execution thrust's goal is faster, proactive, and timely planning and scheduling which will be coordinated across multiple components. The payoffs include the following:

- Dynamic, high confidence decision environment throughout the C2 system
- Capability for predictive planning and preemption, integrated force management and execution
- Capability for real time sensor to decision maker to shooter operations
- Collaborative, distributed real-time mission planning and training
- Collaborative/distributed battlespace simulation
- More than 50 percent reduction in planning time and staff; 100 percent speed-up in knowledge, information gathering, and retrieval
- Distributed automatic plan generation for force employment, deployment, and monitoring
- Dynamic replanning to increase overall operations tempo by 10-fold
- Coordinated planning among several commanders and coalition forces
- Ability to adapt dynamically to changing environments and uncertain information

Global Information Exchange

Global Information Exchange is the ability to interconnect anywhere, at any time, and for any mission all members of the Air Force via a secure, survivable, high capacity, netted communication and information system. Inherent in this capability is the idea of universal information availability across different transmission media with different characteristics. The Air Force's information network must have global reach for its normal day-to-day operations as well as the capability to allow an instant surge of connectivity and capacity into a localized theater for mobile and fixed-site users.

Global Information Exchange Subthrusts

- Global Communications
- Defense Information Warfare
- Information Systems and Networking

The Global Information Exchange thrust has three subthrusts: Global Communications, Defensive Information Warfare, and Information Systems and Networking. Global Communications goals center on wireless information exchange systems and technologies that interconnect remotely separated command and control systems and users, providing high quality, timely, secure and low-probability-of-exploitation communications to air, land, and space. These services include voice, data, and multimedia with linkage to land-based terrestrial networks. The required capabilities provide line-of-sight and beyond-line-of-sight connectivity spanning the frequency ranges. Defensive Information Warfare is concerned with the defense of friendly information systems to ensure the authorized use of the information spectrum. This technology seeks to protect against corruption, exploitation and destruction of friendly information systems; ensure confidentiality, integrity and availability of systems; and integrate actions (offense, defense, and mitigation) to ensure an uninterrupted flow of information for weapons employment and sustainment. Information Systems and Networking will develop and integrate information-related technologies to improve operational C4I capability in a worldwide military/commercial infrastructure environment. Information systems management, network management and communications technologies need to be integrated to provide in-transit visibility of aircraft, airborne situational awareness, and warfighter reachback on diverse airborne platforms.

The Global Information Exchange thrust provides information anywhere, anytime, for any mission through adaptable and scaleable communications. Its payoffs include:

- Supporting information that enables the development of seamless collaborative workspaces
- Providing a 1,000 times increase in global connectivity to aircraft in terms of both data rates and availability of services
- Providing 24-hours-a-day in-transit situational awareness and visibility of personnel/aircraft/cargo status
- Providing worldwide information for decision-makers, planners, and warfighters
- Providing information warfare attack detection and recovery as an underlying service of the global infosphere
- Support assured and survivable networking in a global information system infrastructure

5.3.4 Relationship of Other S&T Programs to Information ETA

This ETA provides enabling technologies to five of the 13 Integrated ITTs and will provide technologies to support eight ITTPs (Table 5-4).

Significant funding to the Information ETA is provided by DARPA, NIMA and others. In addition, commercial information technology is growing rapidly. Thus, an emphasis is being placed on direct commercial exploitation, assessment of COTS technology for military applications, and cooperative research and development with industry, academia, and other government organizations.

AFRL has also led the creation of the Information Institute (II), a collaborative forum between United States academic institutions with strong information technology programs and information enabling technologies. The II will stimulate innovation in information technology programs and leverage on-going information technology research in academia.

Space Superiority ITT
• Space-Based Radar • Space Operations Vehicle • Hyperspectral Imaging • Space Optics & Laser Technology
Precision Strike ITT
• Automatic Target Recognition • Real-Time Sensor-to-Shooter Operations* • Unmanned Combat Air Vehicles
Information Dominance ITT
• Configurable Aerospace Command and Control • Defensive Information Warfare* • Consistent Battlespace Pic ture* • Global Grid* • Dynamic Command and Control*
Training for Warfighting ITT
• Warfighting Operations Center Training • Simulation and Distributed Mission Training
Agile Combat Support ITT
• Deployment Planning, Command and Control, Reduced Airlift and Sustainment • Force Protection **Led by AFRL/IF*

Table 5-4: Information ETA Relationship to ITTPs

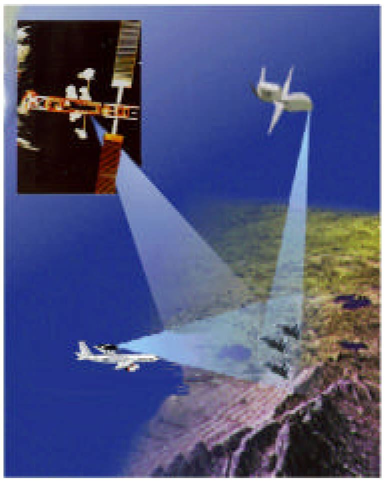
5.3.5 Information ETA FY25 Vision

This information ETA will continue to proactively pursue innovative technologies and strategic partnerships enhancing U.S. information dominance in the 21st Century. Its vision for FY25 is focused in three areas: Global Awareness, Dynamic Planning and Execution, and Global Information Exchange.

Global Awareness will be achieved through a single, integrated battlespace picture to support operations. It will provide a fifty-fold increase in amount of data utilized, and a hundred-fold increase of information fusion with scaleable resolution and accuracy with a thousand-fold increase in storage and processing of information on platforms. Global Information Exchange will provide information anywhere, anytime, for any mission through adaptable and scaleable communications, but missions will have expanded into Space, and may include SpacePlane vehicles and other Space Force information requirements and resources. The scope of the Global Information Exchange Thrust will continue to include widely distributed and mobile C2 (now including "in-space" assets), in-transit visibility (for airborne and spaceborne vehicles), information on demand, information warfare attack detection and recovery, and assured survivable, and self-healing networking technology. Dynamic Planning and Execution will help a commander shape and control the pace and phasing of engagements through a worldwide distributed decision-making infrastructure of virtual battlestaffs and intelligence information specialists.

5.4 Sensors

"Sensors for Information Superiority and Global Awareness"



Sensor systems provide the signals, images, and target/threat information needed to build an interactive common battlespace picture - providing comprehensive, accurate, and timely situational awareness for the warfighter. The platforms of the military force that respond to a hostile situation must rely on their sensor systems for effective target/threat engagement and self-defense. Sensor systems are among the most critical of military assets, needed throughout the timeline of military operations. The vision of the Sensors ETA is to develop a full range of affordable air and space sensors, networked to the warfighter, that assure a complete and timely picture of the battlespace for precision engagement and survivability. The Sensors ETA will develop technologies needed by DoD to produce, field, and maintain advanced sensors for air and space reconnaissance, surveillance, precision engagement, and electronic warfare applications. Key areas include radar, active and passive electro-optical (EO) systems, electronic support measures and countermeasures, navigation aids, Automatic Target Recognition (ATR) and sensor data fusion.

5.4.1 The Planning Context for Sensors ETA

Joint Vision 2010 and the Air Force's vision of Global Engagement identify information superiority and global awareness among their most critical elements. They cite the need for a truly interactive common battlespace picture.

The AFSP supports these visions with specific actions to focus its core competencies achieving the highest priority future capabilities for the warfighter. Capabilities that the Sensors ETA is developing critically needed technologies for are: identify critical technologies needed to sense, identify and track all air and surface targets and threats anywhere in the world and in any kind of weather; to counter difficult targets (weapons of mass destruction, concealed, and low observable); to protect air and space assets; to control the electromagnetic spectrum of the battlespace; and to rapidly prosecute time-critical targets and threats.

In addition to the strategic guidance provided by Air Force leadership and the warfighter customers, the Sensors ETA planning incorporates science and technology development guidance from the SAB, the DTAP and the JWSTP.

Feedback from recent SAB reviews provides specific guidance that this ETA will develop technologies to measure, collect and interpret important military information worldwide. This ETA needs to transition from a platform-centered perspective to system, battlespace, or global awareness perspectives. It will maintain a balanced investment strategy that supports the full spectrum of technologies needed to address Air Force warfighter capabilities and pursue future revolutionary concepts.

5.4.2 Investment Strategy for Sensors ETA

This ETA has three investment strategies. The first is to exploit new sensor phenomenology and architectures to lead the state-of-the-art and inspire revolutionary system concepts and military capabilities. The second is to provide sensor technologies to support the efficient operation of a full-spectrum, multi-directorate revolutionary technology and system concept development partnership. The third is to support warfighter needs of the MAJCOMs to assure that the United States can field the most affordable and effective fighting force in the world.

5.4.3 FYDP Investment Strategy for Sensors ETA

To achieve these objectives, the Sensors ETA's investment strategy is organized around three technology development thrusts. These thrusts are: Radio Frequency Sensors and Countermeasures (CM), Electro-Optical Sensors and Countermeasures, and Automated Target Recognition and Sensor Fusion. To assure sensor technologies are also relevant, technology investments and weapon system applications are tracked within three application objectives that cross-cut the technology thrusts: ISR; precision engagement (PE); and electronic warfare (EW). An additional crosscutting view is maintained for militarily unique electronic devices and components that have pervasive application within a variety of sensor systems.

Sensors ETA Thrusts

- Radio Frequency Sensors and Countermeasures
- Electro-Optical Sensors and Countermeasures
- Automated Target Recognition and Sensor Fusion

Radio Frequency Sensors and Countermeasures

The RF Sensors and Countermeasures thrust develops technologies for airborne and space-based RF sensors to perform all-weather threat/target acquisition, tracking, and identification; platform self defense; and counter enemy command, control, intelligence, surveillance and reconnaissance. Specifically included are airborne and space-based radars for target detection and tracking and EW systems for electronic attack and electronic protection. Supporting technologies include low cost compact antennas, digital and optical beam forming, high dynamic range digital receivers, adaptive processing, RF phenomenology, and high performance/militarily unique electronic components.

Radio Frequency (RF) Sensors and Countermeasures Subthrusts

- Radar
- Electronic Warfare
- Assured Reference
- RF Apertures
- Algorithms and Phenomenology
- Digital Receivers and Exciters

The RF Sensors and Countermeasures thrust has six subthrusts: Radar, which includes detection of difficult targets, space-based radar, and tool development, electronic warfare (EW), including electronic attack, electronic protection and C3 countermeasures; Assured Reference, which includes GPS modernization, inertial technology and integration technology; RF apertures, which includes large, lightweight antennas, conformal arrays, multi-function, multi-mode antennas and digital beam forming antennas; Algorithms and Phenomenology, which includes adaptive processing, detection and tracking, waveform diversity and phenomenology; and Digital Receivers and Exciters, which include EW, radar, and GPS.

The primary goals of this thrust are to develop aerospace RF sensors and components for the warfighter that are mission essential, affordable and reliable. The following payoffs will be realized on or before 2005:

- Lightweight, compact surface mount active apertures for UAVs
- SBR phased array antennas for Ground Moving Target Indication (GMTI) and Airborne Moving Target Indication (AMTI) applications
- Digital beam forming techniques for improved LO detection
- Multifunction digital receivers for SBR ISR
- Militarily essential space electronic components to provide lower power dissipation, high speed analog-to-digital converters
- RF bistatic clutter models and adaptive processing techniques for F-15, F-22 and JSF radars
- Detection of underground and nuclear, biological and chemical (NBC) facilities from aerospace platforms
- Flight test demo of Foliage Penetrating (FOPEN) radar with 85 percent form, fit, and function for TII+ UAV
- High antijam digital/optical/spatial/temporal GPS signal processing capabilities
- Electronic protection capabilities for space based sensors
- Electronic attack concepts for satellite survivability

Electro-Optical Sensors and Countermeasures

Electro-Optical (EO) Sensors and Countermeasures Subthrusts

- Target Detection & Identification
- Threat Warning & Countermeasures
- EO Receivers
- EO Transceivers
- Algorithms and Phenomenology

This thrust conducts advanced and exploratory development of technologies and systems needed to assure that Air Force aerospace vehicles accomplish the full scale of their future missions. Research will be focused on technologies for space, but could provide any aerospace vehicle the capability to rapidly search, detect, identify, and acquire targets, over large geographic areas. The warfighter will use this information to optimize the use of weapons as well as conduct aerospace vehicle self protection against guided/directed threats that operate in the optical/infrared spectral regions. Hyperspectral sensor technologies and Laser Detection and Ranging (LADAR) technologies will be developed and integrated into systems to detect, identify and negate targets in all weather conditions. Laser technologies will be developed to provide high speed, high bandwidth, and low probability of intercept communication between aerospace vehicles. The thrust will also incorporate into our aerospace vehicles active, laser-based countermeasures as well as new expendables to significantly enhance their survivability against the future, sophisticated EO/IR threats.

The EO Sensors and Countermeasures thrust has the following subthrusts: Target Detection and Identification, which includes large area search/detection, precision/difficult targeting, NBC detection and ID; Threat Warning and CM, which includes large aircraft IRCM, day/night EO/IR tracker CM, new flares and expendables, all aspect threat warning, threat warning/attack reporting, and laser warning; Receivers, which includes hyperspectral sensor imaging (HSI) receivers for target search, detection and threat warning, multi-dimensional imaging sensors, and receivers for eye-safe LADAR; Transceivers which includes frequency agile laser sources, non-mechanical beam steering, long-range, robust laser radar, multi-discriminant EO sensors, and laser communications; and Algorithms and Phenomenology which include n-dimensional LADAR techniques; HSI phenomenology and techniques, imaging threat investigation, and multi-discriminant EO sensors.

The EO Sensor and Countermeasures thrust has two primary goals: provide affordable, long-range, all weather, day/night detection and identification of non-cooperative and deep-hide targets, and provide affordable protection of the Air Force aerospace vehicles from a lethal and potent EO/IR threat.

The thrust will complete the advanced and exploratory development of technologies that will achieve the following payoffs by 2005:

- 100 percent increase in 2-D target detection and identification range
- 70 percent increase in large-area search/detection capabilities in air and space through hyperspectral imaging algorithm development
- 40 percent increase in targeting effectiveness with image stabilization/interaction/enhancement algorithm development
- 40 percent improvement in missile approach warning via advanced multi-spectral detection/ID algorithms
- 50 percent increase in air-to-ground/air-to-air non-cooperative target identification via long range, vibration imaging LADAR
- 60 percent increase in aircraft protection against imaging seekers through countermeasures development and demonstration
- 33 percent better life cycle cost and a 20 percent reduction of false alarms for warning sensors
- 50 percent improvement in expendable decoy protection of large aircraft with new IR flares

Automated Target Recognition and Sensor Fusion

> **Automated Target Recognition and Sensor Fusion Subthrusts**
> - Space and Air Sensors Automated Target Recognition
> - Precision Identification and Location
> - Automated Target Recognition Spiral Development
> - Innovative Algorithms
> - Target and Phenomenology Modeling
> - Evaluation Science

This thrust provides warfighters with enhanced capability to rapidly find, fix, identify, and track targets on the surface, in the air, and in space, from airborne and spaceborne platforms. This ATR capability must be timely and accurate enough to prosecute time critical targets under the variety of conditions encountered in both military conflicts and peacekeeping missions. The ATR Thrust works closely with the RF and EO Sensors Thrusts to process and fuse sensor signals to find, fix, identify, and track all targets of military significance in the battlespace.

The ATR and Sensor subthrusts include Space and Air Sensors ATR, which includes synthetic aperture radar ATR, RF moving target ATR, multi-sensor ATR, and hyperspectral ATR; Precision Identification and Location, which includes combat ID and fire control for air and space superiority, special operations forces, and combat ID for time critical targets and other air-to-surface missions; ATR Spiral Development, which includes modeling, simulation, and integration, ATR environment and data generation; and Innovative Algorithms, which includes physics-based ATR, adaptive ATR and resource management for ATR; Target and Phenomenology Modeling, which includes computational electromagnetics (CEM), computer-aided design (CAD) model development, electromagnetic (EM) phenomenology and validation, modeling and simulation physics and application objective support; and Evaluation Science, which includes performance theory, and evaluation experiments.

The primary goals of the ATR and Sensor Fusion thrust are to provide warfighters with ability to rapidly and continuously find, fix, identify, and track all military targets in the battlespace from space and air, thereby improving combat mission effectiveness and maintaining total battlespace awareness. The following payoffs for a class of baseline air vehicles (F-117, F-15, C-130, U-2, Global Hawk) will be achieved by the year 2010:

- Fix to less than one meter and identify 95 percent unhidden targets, identify 80 percent hidden targets with minimal degradation due to adverse weather conditions
- Maintain sufficient track quality on all identified mobile targets so that they can be acquired and successfully engaged with 95 percent confidence
- Provide automated decision information to facilitate engagement of all targets of interest effectively with 95 percent or greater confidence
- Assess target engagement effectiveness with 95 percent confidence within minutes to hours, depending on specific target priority
- Conduct entire F2AT2E cycle within ten minutes/(time critical target) to 2 hrs/(time sensitive target)

5.4.4 Relationship of Other S&T to Sensors ETA

The Sensors ETA provides support to five of the six ITTs and to 19 ITTPs. This relationship is displayed in Table 5-5.

In the area of Dual-Use Technologies, the Sensors ETA programs include the development of affordable electronically scanned array antenna technologies, low cost digital receivers, infrared distributed apertures, four-inch indium phosphide wafers, and multifunction laser radar. These programs are in direct support of air and space needs while advancing the state-of-the-art in telecommunications, advanced automotive sensors, and wind profiling for precision airdrop and commercial flight safety. This ETA is also working closely with U.S. allies to jointly develop sensor technologies. The international programs include Electronic Warfare Systems (EWS) and Sensors (SEN) Groups under the Technical Cooperation Program (TCP), NATO Study Panels, NATO Quadrilateral Combat ID, the OSD/USAF Nunn Real-Time Information into the Cockpit (RTIC) Project with Italy, and bilateral projects with the United Kingdom, Israel, Sweden, and France.

Under the direction of OSD, the Sensors ETA plays a prominent role in the development of the coordinated joint-service technology development plan. ETA investments are documented within two DTAPs: Sensors and Electronics and Weapons (the EW component). In addition, the needs for sensors technology are described in the JWSTP.

Jointly with AFRL's Air Vehicles Directorate, the ATR and Sensor Fusion Thrust is maturing ATR and sensor fusion technologies for rapid exploitation of spaceborne sensor signal data and applications to include Warfighter and Discover platforms. The ATR and Sensor Fusion thrust will mature ATR for millimeter microwave (MMW), laser sensors on munitions, powered LOCAAS, and SSB applications.

Space Superiority ITT
• Space Operations Vehicle • Space Based Radar* • Space Optics and Laser Technology • Hyperspectral Imaging • Space System Survivability
Precision Strike ITT
• Small Smart Bombs • Low Cost Autonomous Attack Systems • Automated Target Recognition* • Real Time Sensor-to-Shooter Ops • Electro-Optical Countermeasure/ Infrared Countermeasure* • Unmanned Combat Air Vehicles
Information Dominance ITT
• Configurable Aerospace Command and Control • Defensive Information Warfare • Consistent Battlespace Picture • Global Grid • Dynamic Command and Control
Agile Combat Support ITT
• Active Denial Technology
Training for Warfighting ITT
• Warfighting Operations Center Training • Simulation and Distributed Mission Training
* *Led by AFRL/SN*

Table 5-5: Sensors ETA Relationship to ITTPs

5.4.5 Sensors ETA FY25 Vision

The Sensors ETA will continue to proactively pursue innovative technologies and strategic partnerships enhancing U.S. sensor dominance in the 21st Century. Its vision for FY25 is focused in three areas: RF Sensors and Countermeasures, EO Sensors and Countermeasures, and ATR and Sensor Fusion.

RF Sensors and Countermeasures will provide sensors for supporting the warfighter to improve space superiority, flexible strike, and EAF protection. Specifically, RF sensor technologies will be developed to enable multifunction micro-satellite ISR capabilities and very compact, flexible radar. EW sensors will be developed to support multifunction UAVs for global awareness and survivability requirements.

EO Sensors and Countermeasures will seek revolutionary and enabling technologies to support the warfighter kinetic kill countermeasure system; a laser threat warning system for air vehicles and space-borne assets; hyperspectral imaging for detection and identification of hidden/camouflaged targets; threat missile warning; multi-band lasers to countermeasure a wide variety of threat systems; secure laser communications for aerospace vehicles; LADAR technologies for ground and airborne targets; non-mechanical beam steering technologies and multi-functional EO systems which provide offensive and defensive capabilities within one configuration.

ATR and Sensor Fusion will provide advanced ATR and sensor fusion algorithms that will be able to process currently unexploited sensor signals and fuse these with existing sensor information to improve friend or foe target recognition. It will provide advanced ATR and sensor fusion algorithms and tagging techniques that can detect and track potential targets. Advanced ATR and sensor fusion techniques that allow reliable detection, identification, and tracking of NBC weapons of mass destruction, as well as their pre-assembly components, will become a reality. Advanced ATR and sensor fusion techniques will be developed to allow reliable detection, identification, and tracking of deeply hidden targets. Rapid target modeling and insertion for rapid updates into algorithms for multiple sensor phenomenology ATR and cross-sensor fusion will also become available.

5.5 Munitions

"Highly Effective, All Weather Conventional Weapons for Global Engagement"

The vision of the Munitions ETA is to develop affordable and highly effective armament technologies to enable warfighters to efficiently accomplish wartime objectives in all weather conditions. The goal is to continuously improve the existing munition fleet through pre-planned product improvement (P3I) of existing systems and development of a minimal number of new systems. This ETA will develop technologies for affordable new weapons that will come online in the new millennium. The technology investment strategy recognizes four integrated development areas that are crucial to accomplishing these objectives: Antimateriel Munitions, Hard Target Smart Munitions, Miniaturized Munitions, and Air Superiority Missiles. The four integrated products will provide capabilities to attack either hard or soft ground targets, and will miniaturize munitions to improve agile logistics and improve weapon loadouts for multiple kills per pass. They will provide a level of autonomous attack necessary to gain air superiority through attack of adversarial defenses. More affordable weapons will be required to attack all varieties of ground targets including mobile, soft, and hardened assets. Improvements in seeker technologies will be required to support global attack in all-weather scenarios. Defeat of hardened targets will be of paramount importance to nullify weapons of mass destruction.

5.5.1 The Planning Context for Munitions ETA

This ETA's efforts directly support two Global Engagement core competencies: Precision Engagement and Global Attack. Munitions development programs are designed to bring the user capabilities to destroy all types of ground targets even if hardened. A major thrust in munitions technology will support Rapid Global Mobility by decreasing the size of munitions while keeping the same explosive power so that fewer will be needed to destroy any given target. Munitions will be much easier to supply to theaters of operation since they will be smaller and much more effective.

The SAB identified autonomous weapons as a major improvement that will be needed by the warfighter in the future. The munitions technologies are directed at the offensive firepower needed by operational Air Forces to perform counter-land and counter-air operations. Increasing the precision of weapons is important for air-to-surface weaponry to support the concept of precision engagement outlined in *Joint Vision 2010*. This ETA program is developing the technologies to accomplish this precision autonomous attack through the LOCAAS. To improve counter-air, a larger avoidance-envelope is being developed to provide the necessary improvement in air-to-air performance to maintain air-superiority.

The DoD has identified proliferation of weapons of mass destruction as a major problem. The counterforce capabilities are being developed that will be necessary in the next century to provide the punch in any counter-proliferation program. A thrust is devoted to developing the technologies that will be required to attack hardened targets. This thrust includes the required precision seekers, the penetrating warheads, multi-event counting fuzes, agent defeat payloads, and a minimum-size weapon that can be carried by any attack aircraft. A major consideration in this development will be to minimize collateral damage from any released agents.

5.5.2 Investment Strategy for Munitions ETA

The Munitions ETA will continue to invest in those technologies that will improve the capabilities to attack and destroy all types of threat targets with extreme precision. These targets include weapon platforms, hardened underground storage and manufacturing facilities for weapons of mass destruction, logistics facilities, and command and control bunkers. These targets will be eliminated with little or no collateral damage. Also, an air-to-air missile capability will be developed that will target hostile aircraft well beyond visual range and will be central in maintaining air superiority.

5.5.3 FYDP Investment Strategy for Munitions ETA

Munitions ETA Thrusts
• Antimateriel Munitions • Hard Target Smart Munitions • Miniaturized Munitions • Air Superiority Missiles

The munitions program has been redirected over the last few years to be highly compatible with the new EAF. The performance parameters that will help make the EAF possible are significant downsizing of armaments while maintaining or improving threat kill capability. This downsizing of weapons will improve aircraft loadout, while simultaneously reducing the logistic requirements that are key to an EAF.

To attain the Munitions ETA vision of affordable technology options for air-launched munitions to defeat ground fixed, mobile/relocatable, air and space targets, there are four thrusts that will be pursued: Antimateriel Munitions, Hard Target Smart Munitions, Miniaturized Munitions, and Air Superiority Missiles.

Antimateriel Munitions

Low Cost Autonomous Attack System

Antimateriel munitions are weapons built to attack soft and mobile targets. These destroy valuable infrastructure and transportation assets that adversely effect an enemy's ability to provide a ground war or re-supply troops. This thrust is developing the integration technology for the warhead, seeker, and airframe subsystems and demonstrating the performance and effectiveness of the munition concept against the full spectrum of ground mobile and relocatable targets with emphasis on improving single shot probability of kill. A key aspect of this thrust is the development and demonstration of a low observable, low drag, standoff dispenser for the anti-materiel submunition. Technologies for all-weather operation and enhanced effectiveness will be matured.

In the near-term, this thrust will develop packaging technology for integrating the submunition into the tactical munition dispenser and internal carriage on F-22, Joint Strike Fighter (JSF), and UCAV as well as dispensing, and stabilizing the submunition after being dispensed. The thrust will also develop and demonstrate a powered LOCAAS weapon. The following payoffs will be realized:

- Improved single shot kill probability
- Multiple kills per pass
- Large search area
- Multi-mode warhead
- All-weather operation
- Low cost

Hard Target Smart Munitions

Smart Munition Attacks Concrete Target

Hard Target Smart Munitions (HTSM) attack the adversary's hardened assets, such as command and control bunkers and fortified weapon storage facilities. To accommodate this thrust, it is necessary to develop multiple concepts with common elements. These common elements can then be exploited to defeat the entire target set. The target set includes high value weapons of mass destruction (WMD), hardened buildings, ammo storage facilities, deeply buried structures and other hardened targets. HTSM customers provide prioritized, time-phased operational needs that fall within the hard and deeply buried target class, yet have diverging mission requirements. To maintain a focus on the customer requirements, the HTSM thrust is divided into two subgroups: one that identifies a technological vision for developing penetrating counter-proliferation weapons and another that identifies a technological vision for developing weapons to defeat deeply buried targets. As potential adversaries continue to develop WMD capabilities and harden their facilities, HTSM performance must be improved to defeat these high-value hardened targets.

In the near-term, this thrust will develop advanced penetrators, fuzes, payloads, and guidance that are capable of denying, disrupting or destroying deeply buried targets. The suite of munition technologies must survive high velocity impacts. Multi-event hard target fuzes will be developed for counter-proliferation missions. Boosted munition concepts will be developed for possible use as test surrogates to replicate conventional ballistic missile penetrators. All-weather guidance systems must be capable of obtaining adequate accuracy to eliminate the targets functionally. Real-time battle damage assessment is required for improved mission planning and to reduce sortie generation rates. All technologies must be modeled via computer simulations so that proper funding and technical decisions can be made. These technologies will be relevant to hypersonic/space delivery weapons as well as to lower speed air delivered munitions. Technical support will be provided to other DoD agencies that are evaluating various penetrator munition concepts. This support may include providing a test item, collecting test data, and analyzing these data. Other payoffs include:

- Creating a biological/chemical defeat capability
- Increased penetration depth
- Increased explosive efficiency
- Battle damage indication/assessment
- All-weather operation

Miniaturized Munitions

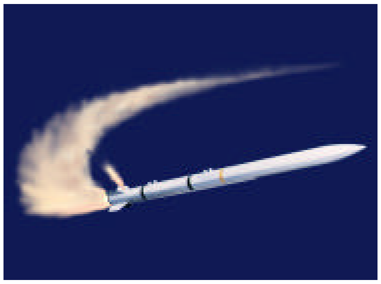

Increased Firepower in Smaller Packages

Miniaturized Munitions will increase the firepower of the Air Force fleet of war fighting aircraft by packing the same lethality into much smaller but more accurate packages. These munitions will also be a key to minimizing the size of aircraft needed, which improves cost and visibility. The downsized munitions will considerably improve the logistics tail of conventional weapons. This thrust is developing a 250-pound class munition with a penetrating warhead and accurate guidance, compatible with very low cost standoff technologies. Enhanced energy and kill mechanism technologies are being emphasized. An all-weather, precision terminal seeker compatible with the concept will be developed.

In the near-term, the thrust will develop and demonstrate precise guidance, navigation, and control for the baseline 250-pound class-penetrating munition. Guidance improvements will include a LADAR seeker and antijam GPS/INS packaged for the six-inch Smart Small Bomb (SSB) diameter airframe. In addition, technology will be demonstrated to enable the SSB concept to be used in a close-air-support role. A critical aspect will be ensuring positive designation of the correct target, especially when dropped from an internal bay. A folding wing kit will be demonstrated to extend munition flyout range. A major integration effort will be required to demonstrate carriage, initialization, and dispense of multiple weapons carried on a single store station. The SSB dispenser will be capable of releasing single or multiple weapons as the attack plan dictates. Munition effectiveness will be enhanced through an improved ordnance package consisting of higher energy explosive, preferential fragmentation, and autonomous hard target fuzing combined with a precise height of burst control for surface targets. Alternate payloads will also be investigated with the goal of limiting collateral damage in an urban combat environment. For defeat of surface fixed WMD targets (chemical/biological production/storage facilities), low-blast configured explosive charges combined with fragmentation control will be pursued. The preferred test aircraft platforms include the F-15E, F-16, F-117, and B-lB. Other payoffs include the following:

- High accuracy for 250-pound class munitions
- Extended flyout range
- Improved ordnance with high energy explosive
- Single or multiple SSB weapon release
- Penetration through six feet of concrete
- Multiple event autonomous fuzing
- UCAV compatibility

Air Superiority Missile



Air Superiority Missile Airframe Concept

Air Superiority Missiles meets the Air Force requirement for an air-to-air missile that will assure global superiority in any conflict. If the Air Force can control the air lanes it may use the other assets developed above to attack surface targets at will. This thrust is developing and demonstrating guidance and control technologies for enhancing the close-in combat capability of air-to-air missiles. It is also pursuing terminal seekers with extended acquisition range, and advanced propulsion for extended flyout ranges. Technologies for expanding the off-boresight launch angle capability are being emphasized. Ordnance technologies for increasing the probability of kill against such targets as cruise missiles and bombers are being identified and pursued.

In the near-term, the thrust will develop and demonstrate flight controls and guidance technologies for enhancing AMRAAM inner boundary/off-axis performance to provide a basis for a near-term Air Superiority Missile airframe concept. Emphasis will be placed on advanced propulsive controls and propulsion energy management technologies and advanced missile autopilot/guidance methodologies for increased flyout range, increased average velocity, and increased maneuverability. Seeker technologies will also be pursued for expanding target off-boresight acquisition capability, increased acquisition range, and increased counter-measure robustness. Technologies leading to multi-mode and/or multi-spectral air-to-air sensor capability will be developed. Ordnance technologies for increasing the probability of kill against cruise missiles will be created. Other payoffs include the following:

- Increased flyout range, average velocity and maneuverability
- Expanded off-boresight acquisition capability
- Increased acquisition range
- Secure two-way data link communications
- Doubled weapon engagement zones and increased survivability

5.5.4 Relationship of Other S&T to Munitions ETA

The correlation between the Munitions ETA and the ITTs of Section 4 is presented in Table 5-6. This ETA provides enabling technologies for three of the six ITTs and nine ITTPs. The Munitions ETA includes joint programs, data exchanges, and technical interfacing with other Air Force organizations, services, government agencies, National Laboratories, industry, and foreign countries. The ETA maintains interface and support programs carried out by these organizations so that it can leverage its technical expertise and fill its technical gaps.

Precision Strike ITT
• Small Smart Bombs*
• Low Cost Autonomous Attack Systems*
• Automated Target Recognition
• Real Time Sensor-to-Shooter Operations
• Unmanned Combat Air Vehicles

Table 5-6: Munitions ETA Relationship to ITTPs

Technologies in this ETA are leveraged with the commercial sector where possible. Resources are invested where there is limited commercial interest, such as in the explosives, warheads, and fuzes areas. Where needed, in-house research is expanded and more military resources are used to advance required technology.

In The Munitions ETA there is a broad-based technology transfer program. Outreach to industry, patenting, marketing, and cooperative efforts are all a part of this area. The Munitions ETA is actively involved with industry through Cooperative Research and Development Agreements (CRDAs) to promote the commercialization of subminiature telemetry, high speed imaging, and layered ceramic materials for gun barrel applications. The ETA is an active member of the Gulf Coast Alliance for Technology Transfer for the purpose of assessing and commercializing its technologies and is also an active member of the Federal Laboratory Consortium for technology transfer. This ETA has several International Exchange Agreements with foreign countries around the world. The primary emphasis is in the ordnance area.

This ETA is also coordinated with the other Air Force S&T technology areas. Special attention is placed on maintaining a close relationship with areas that are vital to armament development such as materials, avionics, air vehicles, and aeropropulsion and power. This awareness ensures that the ETA thrusts can benefit from work performed in these areas.

5.5.5 Munitions ETA FY25 Vision

The munitions ETA is organized to provide synergistic technologies for four major weapon capabilities that will revolutionize the warfighting capability in FY25. The following describes our visions in these four areas. Antimateriel Munitions will provide precision offensive capability with no collateral damage to surrounding populations using both precision and tailorable ordnance programmed by the delivery vehicle to match the target. The autonomous version will be flexible enough to attack a large variety of soft targets with utmost damage. For Hard Target Smart Munitions, the vision is for a 2000-pound class, powered munition, terra navigation, all-weather precision guidance, penetrator capable of penetrating and surviving more than 20 meters of reinforced concrete equivalent. The integration of a high-speed propulsion system will demonstrate standoff, survivability, and capability against high value fixed target. For Miniature Munitions, a multi-purpose Fast Reaction Weapon effective against relocatable and fixed targets will be available. Scramjet hypersonic propulsion will provide the ability to attack relocatable time critical targets at ranges in excess of 500 nautical miles. Advanced high energy (>6X Tritonal) variable yield explosive or a "non-lethal" kill mechanism will be available to enable long term facility denial or less than lethal defeat. For Air Superiority Missile, multi-frequency sensor technologies will lead to large increases in acquisition range and countermeasure robustness and high temperature materials and heat tolerant sensors will enable hypersonic velocities. The goal is to have a true multi-mission capability via advanced propulsion, airframes, seeker and ordnance technologies leading to long range air-to-air and air-to-ground quick strike SEAD capability with a single weapon type.

5.6 Propulsion

"Propulsion and Power Dominance for Space and Air Superiority"

The vision of the Propulsion ETA is to provide preeminent global leadership in military propulsion and power technology. This ETA provides research and development on all Air Force propulsion technologies in order to create and transition propulsion and power technology for military dominance of air and space. This ETA leads the development of propulsion technologies for air and space vehicles including turbine and rocket engines, advanced propulsion systems, and the fuels and propellants on which they run. It also provides leadership for most forms of power and energy conversion technology.

The Propulsion ETA benefits all aspects of Air Force operations by providing balanced improvements in affordability, performance, reliability and supportability. As these improvements are deployed, they are routinely adopted by the other services and the civil sector.

5.6.1 The Planning Context for Propulsion ETA

Joint Vision 2010, Global Engagement, and *Air Force 2025* have provided general guidance to the propulsion community for focusing research activities. Common themes of these planning studies include a desire to carry out joint operations (joint service and multi-national) through expeditionary forces with aerospace dominance. The desire for an expeditionary force capability within the Air Force dictates the need for small but effective air units with enhanced mobility. This requires a minimum logistics tail to be viable. While information dominance may be an important aspect of aerospace dominance, precision engagement and survivability are also key. All these factors drive the user requirements to continue to improve the range, payload, speed, and maneuverability for future weapon systems. In addition, limited resources have made affordability the number one concern of the Air Force. The Air Force's core competencies of Air and Space Superiority, Global Attack, Rapid Global Mobility and Agile Combat Support are dependent upon advanced propulsion and power systems.

For the *Joint Vision 2010* Focused Logistics operational concept, the Air Force Agile Combat Support core competency and the Expeditionary Aerospace Force, which is a desired capability in the *Air Force Strategic Plan* (AFSP), a More Electric Aircraft (MEA) program is required. MEA dramatically reduces the logistics footprint, maintenance requirements, and manpower and has the extended storability of a fluidless system. The MEA program enables more robust defensive weapon systems, thus enhancing full dimensional protection as called for in *Joint Vision 2010*. With further developments, the MEA program will facilitate precision engagement by enabling advanced, lethal, directed energy weaponry aboard tactical aircraft, including UAVs.

Key to the Air Force's vision of Global Engagement is the ability to reach any worldwide location quickly. Advanced, reusable, hypersonic engines are required to enable the development of a military aerospace vehicle (MAV). This need for launch on demand to strike worldwide locations was also identified by the *Air Force Spacecast 2020 Study* which stated that all future Air Force space launch vehicles need to be responsive, highly reliable, able to abort a launch without destroying the vehicle, resilient, flexible, logistically supportable, and easily operated. Additionally cited in the *Spacecast 2020 Study* is the need for high energy density fuels. High-energy density materials (HEDM) include additives and high-energy fuels to improve performance of systems without negatively affecting cost or operability. HEDM efforts are also cited in the *Air Force New World Vistas (NWV)* report. This study mentioned HEDM as having the potential to revolutionize the future of rocket propulsion. Additionally, the report cites a need for high power electric and solar thermal propulsion in an attempt to increase the life of satellites through higher performing propulsion concepts. The need to sustain current strategic missile system capability is listed as one of the top three near term priorities identified by AFSC. The JWSTP also identified the strategic missile capability need and identified specific technology needs to ensure the capability.

The DoD JWSTP identified turbine engine technology needs specifically for aeropropulsion. The plan states that there is still no foreseeable substitute for the firepower and mobility of aircraft and rotorcraft, nor is there a substitute on the horizon for gas turbine engines as the primary airbreathing propulsion system. The direction and focus for future turbine engine technology will place additional emphasis on enhancing engine reliability and durability while providing the needed improvements in performance and power generation. Overarching this will be the requirement to identify technologies which provide exceptional value by reducing the cost of ownership of future turbine engines. In support of this fundamental shift towards an affordability focus, the AFMPP identified turbine engine durability and high cycle fatigue (HCF) aircraft propulsion system deficiencies.

5.6.2 Investment Strategy for Propulsion ETA

The goal of transitioning from an air and space force to a space and air force will place more emphasis on the Aerospace and Space thrusts with the investment in these thrusts growing steadily over the next several years. The Air Force is attempting to expand beyond traditional air technologies into space-focused technologies. The Propulsion ETA's investment principles are consistent with the Secretary of Defense military strategy and the National Science and Technology strategy. Compliance is assured through frequent reviews and guidance from DDR&E, AFMC, SAB panels, and AFOSR.

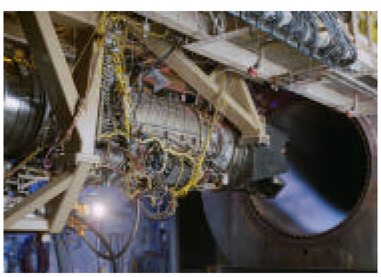
5.6.3 FYDP Investment Strategy for Propulsion ETA

The Propulsion ETA develops near and far term technologies across a broad spectrum of propulsion and power. Currently, the Propulsion ETA invests 42 percent of its funding in near term activities primarily focused at the sub-system and demonstration level. The remaining 58 percent of the current ETA funding is invested in mid-term exploratory development activities to provide evolutionary technologies at the system level. This percentage of funding allocated for advanced development and exploratory development is not expected to change more than eight percent over the course of the FYDP. The Propulsion ETA is divided into four major technology thrusts: Air Propulsion, Aerospace Propulsion, Space Propulsion and Power Technology.

Propulsion ETA Thrusts

- Air Propulsion
- Aerospace Propulsion
- Space Propulsion
- Power Technology

Air Propulsion



Turbine Engine Durability Testing

Air Propulsion has the subthrusts of Aircraft Propulsion and Air Launch Missile Propulsion. The Aircraft Propulsion subthrust includes turbine engine technologies, advanced fuels and lubricants. The Air Launch subthrust includes tactical missile rocket propulsion technology efforts.

Air Propulsion Subthrusts

- Aircraft Propulsion
- Air Launch Missile Propulsion

The Integrated High Performance Turbine Engine Technology (IHPTET) program is a major portion of the near-term aircraft propulsion subthrust. IHPTET is a coordinated program involving the three services, DARPA, NASA, and industry. There is an overall government plan and each of the six aircraft turbine engine manufacturers has a complementary Advanced Turbo Propulsion Plan (ATPP) that addresses IHPTET. IHPTET develops component technologies to increase propulsion system performance while reducing weight, fuel consumption, production cost, and maintenance cost. IHPTET has been further enhanced to improve engine operational reliability. These component technologies are integrated into an advanced Turbine Engine Gas Generator (ATEGG) where the performance, cost, durability, reparability, and maintainability aspects can be assessed in an integrated component-testing environment. The Aircraft Propulsion subsystem Integration (APSI) program includes demonstrator engines such as the Joint Technology Demonstrator Engine (JTDE) for manned systems and the Joint Expendable Turbine Engine Concept (JETEC) for unmanned air vehicles and cruise missile applications. APSI further matures the core technologies as well as addressing some of the systems integration aspects of inlets, fans, turbines, nozzles, engine/airframe compatibility, and low-observable technologies. Near term application of IHPTET technology will enhance the capabilities of systems such as the JSF, UCAV, and F-18/F, as well as provide for upgrades to existing systems. Advanced fuels and lubricants that are thermally stable, cost-effective, and capable of higher temperatures are being developed for use in aircraft and missile engines. Conventional petroleum and alternate fuels are developed and evaluated for Air Force applications. Specific goals for the Aircraft Propulsion subthrust include:

- 100 percent thrust to weight improvement
- 35 percent reduction in production cost
- 35 percent reduction in maintenance cost
- 120 percent increase in fuel cooling capacity (JP-8+225)

Key Air Force guidance in this area is to migrate investment from aeronautics to space, meet customer requirements with the most cost effective technology possible, and pursue fundamental enabling technologies that provide options for tomorrow's Air Force. In the near term, the requirements of JSF and UCAV will dictate a significant investment in turbine engines through IHPTET. In the future, it is anticipated that a further partnering arrangement with the commercial side of government and industry will enable significant advancements in turbine engine versatility and affordability while reducing Air Force investments. This new initiative, termed the Versatile Affordable Turbo Engine (VATE), will have as its primary focus a significant enhancement in propulsion affordability through reduced cost of ownership, including development, production, and maintenance cost. Specific goals for VATE are currently under development, but it is anticipated that an order of magnitude improvement in affordability (i.e., propulsion capability/cost) may be achievable.

The Air Launch Missile Propulsion subthrust focuses on developing technologies that improve both air-to-air and air-to-ground missiles. Programs in this subthrust focus on increasing rocket system impulse, increasing range, decreasing time to target, and reducing cost. The major initiative in this area is developing technologies in both case and propellant improvements to achieve increased velocity and decreased time to target payoffs. The payoffs of this thrust include:

- 15 percent increase in delivered energy of tactical missiles

Power Technology

Revolutionary Power Generation

Power Technology Subthrusts

- Advanced Aircraft Power
- Weaponry Power
- Advanced Spacecraft Power
- Foundational Power R&D

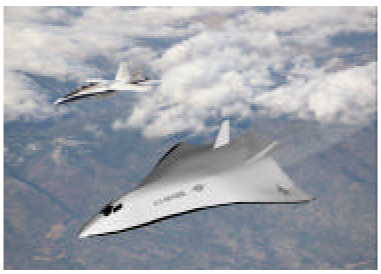
The major focus of this thrust is electrically based secondary power systems for air and space vehicles, both manned and unmanned. Led by the Air Force, the More Electric Initiative (MEI) leverages support from the three services, NASA, and over 50 individual companies. The emphasis is on reducing the cost of force projection by doubling power system reliability and reducing our dependence on aircraft ground support equipment. The "more electric" concept is made possible by successful development and improvement in key power components. These enabling technologies and components are then integrated and demonstrated within the four critical technologies – power generation, power distribution, energy storage, and subsystems interaction. The "more electric" concept will not only reduce support equipment and costs, and improve current aircraft effectiveness but is also seen as the technology direction of opportunity relative to numerous other military and commercial systems.

The MEI will reduce the cost of global force projection by minimizing/eliminating troublesome power subsystems. Existing problem areas include centralized hydraulics, and bleed pneumatic subsystems. This MEI approach mandates a high degree of self-sufficiency, improved reliability, maintainability, and supportability – all yielding a quicker turn-around time. The required maintenance and logistics support for this concept is significantly reduced versus conventional approaches due to the use of line replaceable units and the implementation of a two-level maintenance concept. Improved efficiencies reduce overall heat rejection to the fuel and all aspects of an electric-based system lead to significantly reduced life cycle costs. These combined benefits directly support the user defined needs to reduce deployed logistics/maintenance and increase range, payload, and maneuverability. Additionally, a space power initiative will investigate how to apply the lessons learned from the MEI to space systems. High power required to operate space-based radar and space-based laser systems will only be possible through dramatic improvements in energy storage devices, thermal management and power management systems brought about by this development.

The Power Technology thrust is divided into four subthrusts: Advanced Aircraft Power, Advanced Spacecraft Power, Weaponry Power and Foundational Power Research and Development, which supports the other three subthrusts. The payoffs of this thrust include:

- A 20-fold increase in power system reliability
- A two-fold increase in power unit density
- Reduced support system cost
- Reduced global force projection cost
- Increased power to enable emerging space-based systems

Aerospace Propulsion



Mach 6 Global Reach Strike Aircraft

Aerospace Propulsion Subthrusts

- Trans-Air Space Propulsion
- Global Reach Propulsion

Aerospace Propulsion is a new thrust which is focusing on identifying and developing propulsion technologies needed for advanced Air Force vehicles capable of operating in both air and space environments. This thrust develops and demonstrates propulsion and power system technologies for future aerospace vehicles and their weapons. The near-term focus is on propulsion and power technologies for the first generation of MAVs, such as the space maneuver vehicle component of the military space plane system. First-generation MAVs are likely to employ space-launch flight operations and rely heavily on the existing technology base. The thrust's contribution to these near-term applications stems from ongoing Propulsion ETA efforts planned and initiated before the thrust was created.

Within the FYDP, the primary challenge for the Aerospace Propulsion ITT will be to initiate the development of technologies for the second generation of MAVs. Such vehicles will begin to bridge the gap between complex space-launch operations and flexible aircraft-type operations. They may well employ Combined-Cycle Engines (CCEs), instead of the all-rocket propulsion systems used by the first generation MAVs. These engines are likely to use cryogenic hydrogen fuel for at least a portion of the operating regime and thus have a strong basis in the recent NASP scramjet and present NASA CCE development efforts. New research activities will look far beyond the current technology base and explore innovative propulsion and power technologies to ultimately provide revolutionary military capabilities.

Integration efforts typically focus on component-level integration, such as the structural integration of a fuel tank into an airframe. True technology-level integration is required if MAVs are to achieve the high levels of reliability and operability associated with aircraft-type operations. Current and planned technology development efforts will facilitate the integration of the power subsystems with the vehicle equipment subsystems. For example, fly-by-wire and power-by-wire may well become synonymous for the second generation of MAVs. Similarly, integrating the technologies for the propulsion and vehicle thermal management systems may be critical to minimizing the structural mass fraction of second generation MAVs.

The Aerospace Propulsion thrust has two subthrusts: Trans-Air Space Propulsion and Global Reach Propulsion. The payoffs of this thrust include the following:

- Deliver at least 5,000 pounds of payload globally at average speeds in excess of Mach 4
- Reduce by one-half, the time to deliver payloads against global targets
- Develop propulsion technologies for a SOV capable of delivering 25,000 pounds to orbit
- Reduce the launch weight of a Pegasus-class launch vehicle to less than 25,000 pounds
- Allow for the launch of a 1,000 pound payload into LEO from any B-52, anywhere, any time
- Double the payload mass fraction of expendable MAVs

Space Propulsion

Highly Reusable Booster Engine

Space Propulsion Subthrusts
- Launch Vehicle Propulsion
- Upper Stage/Orbit Transfer Propulsion
- Spacecraft Propulsion

Space Propulsion has subthrusts of Launch Vehicle Propulsion, Upper Stage/Orbit Transfer Propulsion and Spacecraft Propulsion. Through the Integrated High Payoff Rocket Propulsion Technology (IHPRPT) program, the Air Force is closely coordinated throughout the government in much the same manner as stated above for the IHPTET program. AFRL has the lead to develop the technologies for the upper stage as well as the development of the solar thermal propulsion. The development of highly operable reusable propulsion components is done with full cooperation of NASA and will be necessary for future systems the Air Force would desire. Programs increasing the life and durability of turbomachinery will enhance large boost engines as well as smaller upper stage engines. Material efforts to reduce the weight of turbopump housings will help lower the dry weight of engines and other material applications and novel cooling designs will help increase the performance of engines. Development of propellant additives to increase the system performance is underway in both liquid fuels and solid propellant. Efforts in solar thermal and solar electric propulsion will add capability to launch vehicles and life to on-orbit assets. Solar thermal technology is being developed as both a propulsion technology coupled with a power generating system, while Hall effect thrusters, pulsed plasma thrusters and arcjets are all forms of solar electric propulsion that could significantly enhance the life of satellites. Included in the Launch Vehicle Propulsion subthrust is strategic sustainment missile propulsion and hypersonic airbreathing propulsion. Strategic sustainment activities are ensuring the availability of timely, capable and cost effective strategic missiles in the future. Meanwhile, the Hypersonic Technology (HyTech) program is developing a hydrocarbon-fueled scramjet with near-term application to hypersonic cruise missiles and far-term application to the first stage of two-stage-to-orbit reusable launch vehicles. The scramjet will be flight tested under DARPA's Affordable Rapid Response Missile Demonstrator in FY02. This technology base will be extended to develop advanced airbreathing propulsion technology that combines the scramjet with rocket and/or turbine engines for reusable launch vehicles. Such combination cycle propulsion will provide two to five times the payload fraction of all rocket systems, greater operational flexibility, aircraft-like operations, and reduced launch cost. The overall payoffs of the Space Propulsion thrust include the following:

- Improved mass fraction and reduced costs
- Increase expendable payload-to-orbit capability by 22 percent
- Increase reusable payload-to-orbit capability by 206 percent (over the life of the reusable system)
- Reduce payload launch costs by 42 percent to 90 percent
- Increase satellite repositioning capability five-fold
- Increase allowable satellite mass by 30 percent
- Sustainment of current strategic missile system propulsion capability
- Improved operational flexibility and aircraft-like operations

5.6.4 Relationship of Other S&T to Propulsion ETA

This Propulsion ETA provides enabling technologies for four of the six Integrated ITTs and ten ITTPs. as shown in Table 5-7.

Space Superiority ITT • Space Operations Vehicle • Space Based Radar • Space System Survivability • Hyperspectral Imaging
Precision Strike ITT • Unmanned Combat Air Vehicles
Aircraft Sustainment ITT • High Cycle Fatigue* • Turbine Engine Durability *
Agile Combat Support ITT • Deployed Base Support Systems • Deployment Planning, Command & Control, Reduced Airlift and Sustainment * *Led by AFRL/PR*

Table 5-7: Propulsion ETA Relationship to ITTPs

The Propulsion ETA is a key component of the Air Platforms and Space Platforms Defense S&T Panels described in DTAP. This DTAP documents the focus, content, and principal objectives of the DoD S&T effort. The ETA is responsive to S&T strategy issued by the DDR&E and is in partnership with other government agencies, industry, and academia. Joint programs are the most common business practice in the Propulsion ETA. Investment in power technologies for space, for weapons, for aircraft, and for fundamental research is a coordinated effort. Air Force funds are augmented by funding from DARPA, NASA, the Navy, the Army, and BMDO to execute programs that are synergistic with the technical area needs of the contributing agencies. Examples of this broad strategy include MEA, high temperature superconductivity (HTS), and wide bandgap semiconductor research. Investment in electrical power generation, distribution, energy storage, and subsystems technologies, under the auspices of the MEA program, will result in dramatic improvements in reliability and maintainability. BMDO sponsorship of HTS generator development needed for ballistic missile defense is directly contributing to development of the high power generating capability that enables long term Air Force goals for directed energy weapons aboard manned and unmanned aircraft. DARPA funding is presently augmenting AFRL investment in wide bandgap semiconductors needed to fully exploit the benefits of MEA and DEW for the warfighter. Power technologies that contribute to long term storage of UCAVs are expected to reach maturation prior to 2005, while more advanced concepts that enable the development of DEW systems will be ready prior to 2015.

In regard to the civilian sector, spin-offs will continue to be both common and important. Large portions of the Propulsion ETA's developed technologies eventually wind up in commercial products. Air Force S&T is largely responsible for maintaining American dominance and a favorable balance of trade in the aerospace field. This also benefits the Air Force when it buys commercial aircraft and engines for its airlift fleet. In the future, the VATE program approach of enhanced dual-use technology utilization will further expedite the transfer of technologies between the commercial and military communities. The space power research in high energy density storage, power management and thermal management are expected to lead the way for the next generation of commercial space assets.

5.6.5 Propulsion ETA FY25 Vision

The Propulsion ETA is continuously evaluating its ability to revolutionize warfighting via the application of new technology. This ETA recognizes the importance of trans-aerospace propulsion and power issues. The Aerospace Propulsion ITT will ultimately enable development of MAVs capable of true aircraft-type operations. By 2025, the propulsion and power technologies ready for transition to system development will allow for revolutionary military-specific warfighting capabilities supporting Global Engagement: daily sorties, wartime surge capability, assured access to space, and global atmospheric/trans-atmospheric transportation. The propulsion and power technologies matured by FY25 will result in systems that are highly reliable, to enable true aircraft-type operability.

The Air Propulsion thrust is working towards revolutionary changes in turbine engines through IHPTET and VATE. These engines will be ultra-low fuel consumption, high thrust-to-weight and low cost in all phases of an engine's life. The Aerospace and Space thrusts will be focused on the Air Force move from an air force to a space force. Revolutionary power thrust advances in the areas of very high power and electrical power generation capabilities will enable an entire new class of directed energy weaponry for use on tactical airborne platforms. The SOV described in the *Joint Vision 2010* will require extensive development of highly operable reusable engines. Radical changes in propulsion technologies may also be applied. Laser propulsion may revolutionize propulsion to space and reduce costs to orbit to a small fraction of their current level.

5.7 Air Vehicles

"Leading The Development Of Military Fixed Wing Air Vehicle Technologies"

The vision of the Air Vehicles ETA is to deliver the best air vehicle technologies to achieve aerospace dominance against all threats. To achieve this vision of providing full-spectrum aerospace vehicle alternatives to the warfighter, efforts are being focused in four priority areas. The first three areas are Air Vehicles Integrating Concepts – Aircraft Sustainment, Trans-Atmospheric Vehicles (TAVs), and Unmanned Air Vehicles (UAVs). Supporting these Integrating Concepts is a fourth area: Air Vehicles Core Technologies. For Aircraft Sustainment, Air Vehicles will develop and transition the critical technologies to enable the Air Force to sustain the current fleet well into the 21st Century. For the future fleet, Air Vehicles will focus on technologies to ensure increased design life and reduced cost of ownership. This is of paramount concern given today's budget realities and the budget-constrained environment anticipated in the future. In the area of TAVs, Air Vehicles will develop and field critical Space Operations Vehicle (SOV) technologies to enable affordable, quick reaction trans-atmospheric and space capability. This enhanced capability will form the cornerstone for realizing aircraft-like spaceplane operations to achieve the Air Force Global Engagement vision. For the UAV area, Air Vehicles will deliver the technologies to build and field future high payoff UAV alternatives to meet the warfighters' full-spectrum aerospace-vehicle requirements. The fourth area, Air Vehicles Core Technologies, is embodied in three Centers of Excellence (COE). These centers will create and nurture innovative research into breakthrough technologies that will enable revolutionary capabilities to satisfy evolving warfighter needs and prevent technological surprise. These four elements of the Air Vehicles vision will serve as the technology linchpins for developing the aerospace vehicle systems to ensure air and space superiority well into the 21st Century.

5.7.1 The Planning Context for Air Vehicles ETA

Joint Vision 2010 and the *Air Force Strategic Plan* identify air and space superiority as the highest priority elements for achieving aerospace force dominance. This dominance can only be achieved by fielding affordable, robust, high-performance aerospace platforms capable of engaging and defeating any adversary, at any time, at any place on the globe. The key to realizing these affordable, high-performance aerospace platforms of the future is a robust spectrum of enabling air vehicle technologies. These enabling air vehicle technologies are also crucial to realizing other important Air Force core competencies: Global Attack, Rapid Global Mobility, and Precision Engagement.

The *Air Force Strategic Plan* further underscores the need for Air Vehicle technologies to enable its desired future capabilities. Capabilities that the Air Vehicles ETA are developing critically needed technologies for are: the development and employment of seamless air and space forces to achieve aerospace superiority at times and places of our choosing; the global ability to find, fix, track, target, engage, and assess any target of significance in near real time for the purpose of conducting decisive engagement; and the ability to deploy rapidly, employ and sustain aerospace power anywhere in the world.

The Air Vehicles ETA also strives to be responsive to the Defense Reliance technology guidance laid out by the DDR&E as part of a national Fixed Wing Vehicle S&T investment strategy. A national team consisting of the Air Force, Navy, DARPA, NASA, academia, and industry identifies cooperative and individual S&T programs focused on achieving full spectrum aerospace vehicle dominance. The Air Vehicles ETA leverages this national strategic focus to guide its technology investments.

5.7.2 Investment Strategy for Air Vehicles ETA

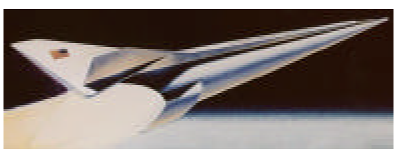
The investment strategy for Air Vehicles is guided by the requirement to provide affordable, revolutionary capabilities to the warfighter that addresses all future threats. The emphasis will be on technology investments that support cost effective, survivable aerospace platforms capable of accurate, quick delivery of a variety of future weapons or cargo anywhere in the world. To achieve this vision, this ETA will invest in three primary areas identified as Integrating Concepts: Aircraft Sustainment, Trans-Atmospheric Vehicles, and Unmanned Air Vehicles. Investments will also be made in three COEs: (1) Computational Simulation, (2) Multivariable and Reconfigurable Control, and (3) Multidisciplinary Technology. These investments provide the technology development needed to fully pursue the respective requirements identified in the Air Force core competencies.

Aircraft Sustainment Integrating Concept

Extend Today's Fleet to Meet Tomorrow's Needs

The goal of the Aircraft Sustainment Integrating Concept is to enable technology insertion to extend today's fleet to meet evolving warfighter needs. Objectives of the concept include increasing the reliability of aircraft systems, reducing depot flow time, reducing operating and support costs and reducing incidents of aircraft loss due to failure. One of the key areas of emphasis within sustainment includes the Aging Aircraft Structures ITTP. Efforts within the structures area will develop and demonstrate technologies for the design and analysis of bonded composite repairs and lead to a methodology to accurately account for the impact of corrosion and cracking on structural integrity and economic service life. A planned effort in weapons bay noise suppression will develop and demonstrate prediction methods and suppression techniques for high acoustic levels in internal cavities. Other ETA efforts include a program to use active core exhaust mixing with pulsed jets to reduce engine exhaust temperature for increased nozzle service life and decreased maintenance and an effort to develop an optical air data system that is more supportable than existing means.

Trans-Atmospheric Vehicles Integrating Concept



Affordable Quick Reaction Trans-Atmospheric Capability

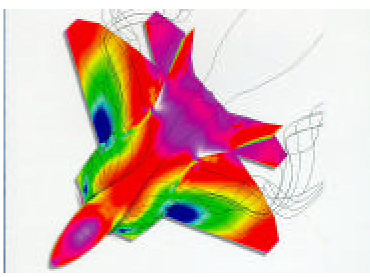
The Trans-Atmospheric Vehicles Integrating Concept supports the need to conduct seamless operations to control the aerospace dimension and enables an affordable, quick reaction, trans-atmospheric and space capability. Emphasis is on Global Engagement in less than three hours, large reduction in reusable launch system life cycle cost, and routine, aircraft-like spaceplane operations. The ITTP for this technology area is the SOV. The SOV is a reusable spacelift architecture designed to drastically lower the cost of access to space while offering flexible, responsive military operations to the Air Force. The SOV System architecture contains a matched booster and multiple upper stage options for two-stage-to-orbit operations. The reusable first stage booster is known as the SOV; upper stage options include the Space Maneuver Vehicle and Modular Insertion Stage. SOV technology investments are worked in close concert with NASA's Advanced Reusable Technologies and Advanced Space Transportation Programs, and will carefully leverage advancements accomplished by existing programs such as X-33, Reusable Launch Vehicle (RLV), X-34, X-38, X-40a, Hyper-X, and Future-X. A critical reason for needing reusable military launch vehicles such as the SOV, is the vast improvement in operability (reduced maintenance hours per sortie, reduced turn times, increased reliability) over the current baseline. An on-going effort to develop mechanically attached thermal protection systems has shown significant promise in this area. Planned programs to develop and demonstrate technologies for inspection and repair of thermal protection systems and composite tanks and structures will also contribute to operability improvements. Basic research is being conducted in active hypersonic flow control by using plasma/weakly ionized gases for drag reduction, flight control, and possibly power generation in conjunction with the Propulsion Directorate. Technology efforts are also planned in the areas of integrated vehicle health monitoring and prognostics, adaptive flight controls, actively cooled structures, and advanced electromechanical actuation. Additional programs are currently being formulated to work technologies pervasive to both SOV and hypersonic cruise vehicles.

Unmanned Air Vehicles Integrating Concept

Technologies for Affordable Routine Operations

The Unmanned Air Vehicles Integrating Concept supports the Precision Engagement core competency and develops and transitions technologies that enable current and future UAV systems that satisfy warfighter mission requirements. UAVs provide revolutionary air vehicle potential with the ability to optimize the aircraft for mission effectiveness without consideration of the pilot. At the same time, the air vehicle must be compatible with essential sensor and information fusion technologies, propulsion and weapons technologies, and must be controllable through an operator vehicle interface. Objectives of this technology thrust include increased flexibility, reliability, and survivability with reduced weight and cost of current and future systems. Complimentary with the UCAV technology demonstrator ITTP, key technology areas include development of reconfigurable flight control and multi-ship cooperative control. Substantial developmental efforts in multifunctional structures such as load bearing antennas, structurally integrated inlets, and fluidic exhaust nozzles are also key for smaller, more affordable systems.

Centers of Excellence



Virtual Prototyping for Reduced Design Cycle Time

Air Vehicles core technologies are developed in three COEs. The Computation Simulation COE emphasizes the development of new pervasive computational methods. One group focuses on basic research in fluid physics, aeroelasticity and electromagnetics, while another focuses on practical implementation and application of multidisciplinary computational techniques. The Multivariable and Reconfigurable Control COE is committed to the aggressive development and transition to the warfighter of advanced air vehicle control technology to improve weapons system lethality and affordability. The Multidisciplinary Technology COE is dedicated to developing the most efficient techniques and processes for integrating different technologies. One focus is the development of new and innovative optimization algorithms. Another focus is the study of technology interactions, such as aerodynamic and servoelastic control, in order to minimize adverse effects and maximize synergism. The final component is new technology applications, such as energy-based design, with a vision of realizing revolutionary air vehicle concepts. In total, the three Centers of Excellence invent and develop new and improved theories and processes to enable revolutionary aerospace vehicle capabilities for the warfighter.

5.7.3 FYDP Investment Strategy for Air Vehicle ETA

To support the Integrating Concepts and the Centers of Excellence, the Air Vehicles ETA has three technical thrusts: Aeronautical Sciences, Structures, and Control Science. The leaders of these technical thrusts will execute the high-payoff programs identified as important to achieving the technology goals for each integrating concept.

Air Vehicles ETA Thrusts

- Aeronautical Sciences
- Structures
- Control Science

Aeronautical Sciences

The Aeronautical Sciences thrust develops critical technologies that sustain the current fleet and enable the Air Force to build and field future UAVs and space vehicles. This thrust is divided into three subthrusts: Computational Sciences, Aerodynamic Configuration, and Aerospace Vehicle Integration and Demonstration. The Aeronautical Sciences thrust conceives, plans, and conducts basic, exploratory, and advanced

Aeronautical Sciences Subthrusts

- Computational Sciences
- Aerodynamic Configuration
- Aerospace Vehicle Integration and Demonstration

development programs to discover, develop, demonstrate, and transition aggressive new technologies for these applications. The SOV will not become a reality without the development of new multidisciplinary design optimization computer codes. These codes are currently under development and will provide affordable computational fluid dynamic solutions for highly coupled aero-thermal-structural problems. New design codes are also under development to optimize wing-body configurations for innovative UAV applications. Results will yield new vehicles with reduced drag for longer range. New theories and techniques are being conceived and matured to understand highly nonlinear aerodynamics for application to UAVs in future high-threat, highly dynamic battle environments. Technology development is underway to develop, evaluate, and facilitate the separation of small class munitions from weapons bays. This technology is vital to ensuring UAV lethality.

Advanced Aeronautical Science technologies yield a reduction in weight, a reduction in design, development, and sustainment costs, an extension of range, an enhancement of maneuverability and stealth, and an increase in payload. The following payoffs will be achieved:

- Increase lift/drag 15 percent
- Reduce lifting/control surface weight/drag 20 percent
- Increase controllable angle-of-attack 30 percent
- Reduce aerodynamic design cycle time 60 percent
- Increase landing approach lift coefficient 25 percent

Structures

Structures Subthrusts

- Extreme Environment Structures
- Structural Sustainment
- Structural Technology Integration

The Structures thrust plans, manages, and conducts research and development programs to solve critical structural problems on fixed-wing aerospace vehicles. These issues are addressed within three sub-thrusts: Extreme Environment Structures, Structural Sustainment, and Structural Technology Integration. These subthrusts advance design, analysis, and integration technology and develop advanced structural concepts and fabrication techniques to improve structural integrity, reduce costs, and reduce weight. They transition developed technology to DoD weapon systems and provide timely solutions to problems arising in DoD and other U.S. aerospace vehicles. Advanced repair techniques and repair design methods developed in the Composite Repair of Aircraft Structures program will provide significant reductions in airframe operations and support cost. The effects of corrosion on the fatigue life of airframe structures will be established in the Corrosion Fatigue program. These life extension and structural integrity methodologies will enable the current fleet of Air Force vehicles to remain viable well past their design life-times. Methods are also being developed to alleviate the effects of buffeting on twin tail aircraft. By reducing the structural vibrations caused by twin tail buffeting, fighter aircraft operations and support cost will be reduced. While working technologies for the current fleet, a robust program has been established to support the future needs of advanced aerospace vehicles such as the UAV and SOV. The Composite Affordability Initiative is providing structures technology for both advanced system types. The Structures thrust will exploit the latest in materials, processes, and manufacturing to produce more durable, lower cost, and survivable structures to meet the needs of the future EAF. Technologies developed by the Structures thrust will lead to a significant reduction in airframe operations and support costs and result in durable, lower cost, and survivable advanced structures. The following payoffs will be achieved:

- Reduce structural manufacturing costs 40 percent
- Reduce structural operations and support costs 35 percent
- Reduce structural development costs 35 percent
- Reduce structural weight 30 percent
- Reduce composite fabrication costs 50 percent

Control Science

Control Science Subthrusts

- Control Technology
- Simulation-Based R&D

The Control Science thrust has two subthrusts: Control Technology and Simulation-Based R&D. Within this thrust, key technologies are developed that enable the Air Force to build and field future UAVs and space vehicles that meet the warfighter's needs and that also affordable sustain the current and future fleet of military aerospace vehicles. The Control Science thrust conceives, plans, and conducts selected basic, exploratory, and advanced development programs to develop, synthesize, demonstrate, and transition bold, innovative control sciences technology for these applications. Within these competencies or subthrusts, technology is advanced in control theory and systems mechanization to enable control of not only single air vehicles, but also the effective control of multiple aerospace systems. For example, control of swarms of UAVs is envisioned, for power projection and wide area as well as enhanced resolution surveillance. This will include not only the evolving class of UAVs, but also future micro-air vehicles. Precision control of swarms of spacecraft coupled with new sensor technology will deliver a new dimension in warfighter information gathering capability. Research in all electric, photonics-based control systems offers substantial weight and O&S cost savings for future UAVs and Trans-Atmospheric Vehicles. This research also delivers viable technology options to reduce operating costs, increase reliability, and provide a "plug & play" information backbone to support future warfighter requirements of our aging fleet. Pioneering flight management technology development is conducted to enable safe, mixed manned aircraft and UAV combat operations in the future high-threat, highly dynamic battlespace. The aforementioned technology developments highly leverage and integrate with our ongoing research in simulation-based R&D to provide a cost effective and science-based approach to concept evaluation and demonstration, delivering findings in not only engineering terms, but also in warfighter measures of merit. This simulation-based R&D environment covers the full spectrum from single aerospace vehicle evaluation through assessment of multiple technologies on a diverse set of aerospace assets in a complex and highly realistic battle environment. Technology developments by the Control Science thrust will reduce aerospace vehicle life cycle costs, improve combat mission effectiveness, and increase flight safety and reliability. The following payoffs will be achieved:

- Reduce control system development costs 30 percent
- Reduce control system operations and support costs 30 percent
- Reduce control systems weight 25 percent
- Reduce control related accidents 75 percent

5.7.4 Relationship of Other S&T to Air Vehicles ETA

The correlation between the Air Vehicles ETA and the ITTs of Section 4 is presented in Table 5-8. This ETA provides enabling technologies to four of the six ITTs and five ITTPs.

The Air Vehicles ETA is a key component of the Air Platforms Defense S&T Panel described in the DTAP. This documents the focus, content, and principal objectives of the overall DoD S&T effort. The ETA is responsive to S&T strategy issued by the DDR&E as part of Defense Reliance and is in partnership with other government agencies, industry, and academia.

Space Superiority ITT
• Space Operations Vehicle *
Precision Strike ITT
• Unmanned Combat Air Vehicles*
• Small Smart Bombs
• Low Cost Autonomous Attack Systems
Aircraft Sustainment ITT
• Aging Aircraft Structures
• High Cycle Fatigue
Agile Combat Support ITT
• Active Denial Technology
* *Led by AFRL/VA*

Table 5-8 Air Vehicle ETA Relationship to ITTPs

5.7.5 Air Vehicles ETA FY25 Vision

The Air Vehicles ETA will continue to proactively pursue innovative technologies and strategic partnerships enhancing U.S. air superiority in the 21st Century. This ETA's vision for FY25 is focused in four areas: Sustainment, Global Presence, Precision Strike, and Innovation and Core Technology.

In Sustainment, the vision is technology insertion to extend today's fleet to meet tomorrow's warfighter needs. It foresees a 50 percent increase in system reliability, a 50 percent reduction in depot flow time, a 50 percent reduction in operations and support cost, and a 50 percent reduction in aircraft loss due to failure.

In Global Presence, the vision is affordable, quick-reaction trans-atmospheric capability. It foresees enhanced aerospace vehicles/spacecraft for improved utility, Global Engagement in less than three hours, 75 percent reduction in life-cycle cost, and aircraft like operation throughout the integrated aerospace environment.

In Precision Strike, the vision is technologies to enable routine operation of high payoff UAV alternatives across the full spectrum of warfare. It foresees a 50 percent reduction in life cycle cost, 10-year shelf life for UAVs, and multi-vehicle cooperative control.

In Innovation and Core Technology, the vision is to create and nurture innovative research into breakthrough technologies, which enable revolutionary warfighter capabilities. It foresees a 90 percent reduction in design cycle time, virtual prototyping, and quantum leaps in warfighter capabilities.

5.8 Human Effectiveness

"Human-Technology Integration for Warfighting Superiority"

The Human Effectiveness ETA plans and executes the Air Force human systems S&T program, providing the enabling technologies for high priority warfighter needs. This ETA's mission is to develop, integrate, demonstrate, and transition affordable S&T products for training personnel, protecting and sustaining the crew member, and improving human interface with weapon systems to assure the preeminence of U.S. air and space forces. The ETA's world-renowned professional researchers, with their state-of-the-art facilities, represent a unique, multi-disciplinary national resource for human-centered technology, fully leveraging the S&T investment by collaborating with the other services, industry, academia, and allies.

The impact of human-centered technologies is pervasive across all current and future operational Air Force systems. The Human Effectiveness ETA's S&T portfolio of basic research, applied research, and advanced technology development is structured to improve the warfighter's productivity in high demand, high-threat, information-saturated environments. This is accomplished by discovering better ways to create seamless interfaces between the human operator and weapon system, train forces, sustain and protect forces over time and distance, and improve their protective equipment.

As the SAB noted in its New World Vistas report, people are the heart of the Air Force's military capability and people will continue to be the most important element of the Air Force's success in capitalizing on change.

The Human Effectiveness ETA's vision is to enhance warrior performance for air and space dominance. The goal is to be the premier DoD organization providing world-class, human-centered S&T. By 2020, the ETA will field the technology so all Air Force systems can be human-centered, from design through development and testing, training, operational use and life-cycle management.

5.8.1 The Planning Context for Human Effectiveness ETA

The guidance for this ETA comes from the Air *Force's Global Engagement: A Vision for the 21st Century Air Force*, in support of *Joint Vision 2010*. That vision's concept of Full Spectrum Dominance, as well as the core competencies of Rapid Global Mobility, Precision Engagement, Global Attack, Air and Space Superiority, Information Superiority, and Agile Combat Support, all directly depend on this technology area.

The Human Effectiveness ETA is strategically planned to be responsive to the near-term and long-term operational requirements of the DoD and the USAF. The near-term needs of the warfighter flow down via the AFMPP, which uses mission needs analysis to derive MAPs and identify deficiencies. This ETA's investments are focused on needs of Air Combat Command, Air Mobility Command, Air Force Special Operations Command, Air Force Space Command, and Air Education and Training Command.

The long-term Air Force operational requirements are described in the *Air Force Long-Range Plan* (AFLRP), which implements the Air Force vision of Global Engagement. This ETA has investments in programs directly contributing to the AFLRP Directives of Integrating Air and Space; Ballistic and Cruise Missile Defense; Battle Management/Command and Control; Unmanned Aerial Vehicles; Presence/Power Projection; Nuclear Weapons Operations, Planning, and Support; Information Operations; Acquisition Management; and Test and Evaluation Infrastructure.

5.8.2 Investment Strategy for Human Effectiveness ETA

Within this planning context is the reality of reduced DoD funding, and the emphasis on affordability issues associated with operating the existing, aging fleet, as well as procuring new systems. As the Air Force continues to experience major funding reductions, this ETA's investment strategy is to partner with others. The Human Effectiveness ETA will pursue integrated, multi-disciplinary, cross-ETA teams to address human system deficiencies across all categories of mission areas. Also, the Human Effectiveness ETA will increase the number of CRDAs with academia and industry to share the cost of development and aid the transfer of human-centered technology to the private sector.

The Human Effectiveness ETA works closely with its Air Force customers to ensure that technology solutions not only meet their operational needs but also are affordable solutions. Emphasizing a maximum return on investment, these S&T programs are focused on technologies that are affordable to the user both in terms of lower initial acquisition cost and lower operations and maintenance costs.

In order to meet the Air Force's requirements for human systems technology, this ETA is divided into four thrust areas: Crew System Interface, Warfighter Training, Deployment and Sustainment, and Bioeffects and Protection.

Each thrust area makes a unique contribution to improving warfighter capabilities and enhancing the operational performance of Air Force personnel. This ETA distributes these Air Force S&T resources among the four interrelated thrust areas.

5.8.3 FYDP Investment Strategy for Human Effectiveness ETA

Human Effectiveness ETA Thrusts

- Crew System Interface
- Warfighter Training
- Deployment and Sustainment
- Bioeffects and Protection

The Human Effectiveness ETA investment strategy over the FYDP reflects the pervasive nature of human needs in air, space, directed energy, and command and control operations. In accordance with AFRL's strategy to be responsive to the Air Force migration to space, the ETA investment is being redirected. The focus of the enabling Human Effectiveness technologies will be more on space and command and control issues, and not as much solely on air issues. Over the FYDP, investments will also be increased in agile deployment and sustainment areas as recommended by the SAB study on EAF. Also, based on a thorough business review which included the needs of the warfighter and the status of technologies, several new emphasis areas have emerged: crew performance and effectiveness aiding technology, visual and aural display technology, training the warfighter, non-lethal technologies, and optical radiation countermeasures.

Crew System Interface

Enabling Technology for the Man-Machine Interface

Crew System Interface Subthrusts

- Information Analysis and Exploitation Technology
- Aural Displays and Bioacoustics Technology
- Crew Station Development Technology
- Human Interface Technology
- Visual Display Systems Technology

The Crew System Interface is that vital link between warfighters and their systems and equipment needed to assure effective air and space operations. Examples of typical crew system interfaces include aircraft crew stations, wearable controls and displays, and ground consoles for myriad applications ranging from individual maintenance personnel to teams of operators collaborating in real-time across the gamut of aerospace operations. This thrust area builds the crew system interface technology needed for tomorrow's aerospace force to match the design of systems and equipment with the warfighter's capabilities and limitations in order to maximize performance and affordability. The Crew System Interface thrust area has five subthrusts: Information Analysis and Exploitation Technology, Aural Displays and Bioacoustics Technology, Crew Station Development Technology, Human Interface Technology and Visual Display Systems Technology.

Information Analysis and Exploitation Technology develops new cognitive information-based interface solutions and human speech processing and control solutions for time-critical command and control, to organize battlefield intelligence data, to eliminate decision-making bottlenecks, to gain a common battlespace understanding and to shorten the timeline for intelligence-to-shooter operations. Aural Displays and Bioacoustics Technology provides the vibroacoustics building blocks of 3-D audio, active noise reduction, digital audio, voice warning and integrated audio/visual symbology in order to enhance crew performance under high noise and vibration while mitigating the adverse effects of noise on the Air Force mission. Crew Station Development Technology develops and employs human-centered analysis models with high fidelity, real-time mission simulation to demonstrate tailored crew station design solutions to answer pervasive questions about control/display placement and function, information requirements and flow, and to exploit the new generation cockpit devices. Human Interface Technology encompasses both the development of physical measurement methods to assure the fit of humans to crew stations and equipment, and complex performance assessment techniques to quantify the human performance contribution to system effectiveness. The quantitative measures are used in conjunction with distributed high-fidelity mission simulations to develop and evaluate cutting-edge interface technologies involving bio-centered controls, multi-sensory adaptive displays, and immersive design - extending and leveraging commercial virtual reality technology. Visual Display Systems technology provides the fundamental vision science and advances the state-of-the-art for visual display technology across-the-board. This technology includes helmet-mounted tracker/displays (HMT/D), night vision goggle (NVG) and panel mounted display technologies, large screen, flat-panel, electronic displays, laser eye protection, synthetic vision and vision through visors, windscreens and heads-up displays. The payoffs of this thrust include the following:

- Achieve reliable stressed voice recognition greater than 95 percent for information operations
- Develop a robust model of the intelligence information fusion process for distributed operations
- Develop a high performance 3-D audio display with active noise reduction
- Reduce hearing loss compensation costs 33 percent with advanced protective device
- Correlation in predicted air engagement effectiveness of 65 percent against real-time simulation data
- Create an integrated task network crew performance model with operations research system effectiveness model for crew tasking
- Develop a 3-D data base of inventory aircraft cockpits and NATO population anthropometry data
- Improve information throughput by 25 percent with multi-channel crew system interface
- Increase air-to-surface kills per pass by 100 percent with HMT/D
- Increase field of view of Panoramic NVG by 160 percent without resolution loss

Warfighter Training

Train the Way We Intend to Fight

The Warfighter Training thrust researches, develops, demonstrates, evaluates, and transitions technologies and methods to "train the way we intend to fight." This thrust area develops and demonstrates distributed mission training (DMT) methods and technologies, demonstrates and transitions training methods and physics-based night vision device training technologies, and develops and evaluates measures of warfighter training effectiveness. The Warfighter Training thrust area has four subthrusts: Space Training, Information Operations Training, Aircrew Training, and DMT Engineering.

Warfighter Training Subthrusts

- Space Training
- Information Operations Training
- Aircrew Training
- Distributed Mission Training Engineering

The Space Training, Information Operations Training, and Aircrew Training areas are all aimed at understanding fundamental learning concepts and then using those concepts to develop training methods in these three domains. Key focus areas within those domains are night vision training, force protection training, and maintenance training. The DMT Engineering area is concerned with developing new technologies and taking better advantage of existing technologies to improve the Air Force's capability to train mission skills on a distributed basis using virtual, live and constructed assets. Specific Warfighter Training Thrust payoffs are as follows:

- Develop embedded training capabilities in space systems
- Create DMT technologies to integrate space forces and air forces training
- Develop technologies for more systematic and structured training strategies for command and control operations

- Develop DMT strategies and technologies for EAF to train on-demand, and as virtual units
- Create technologies and strategies for aircrew currency training in virtual simulators to preserve aging fleet aircraft service life

Deployment and Sustainment

Survivability of Personnel Exposed to Toxic Environments

Deployment and Sustainment Subthrusts
- Readiness Logistics
- Sustainment Logistics
- Operational Toxicology

The Deployment and Sustainment thrust develops and demonstrates technologies that improve the performance, affordability, supportability and readiness of current and future weapon systems and technologies that support the deployment and employment of global EAF operations. This thrust area focuses on logistics support capabilities and personnel protection from hazardous materials during deployment in both combat and military operations other than war. The Deployment and Sustainment thrust area has three subthrusts: Readiness Logistics, Sustainment Logistics, and Operational Toxicology.

Readiness Logistics includes wing and theater-level logistics support technologies and methods to improve logistics planning, readiness, deployment and information systems, along with aids and diagnostic processes for wing level aircraft maintenance. Sustainment Logistics develops, demonstrates, and transitions methods, processes, tools, and equipment technologies to enhance weapon system acquisition, affordability, and supportability from design inception through retirement. This subthrust also develops techniques to improve logistics sustainment of global air power operations through better distribution systems and more effective weapon system support. Operational Toxicology develops technologies to prevent mission degradation due to exposure to toxic and hazardous chemicals and materials across a broad spectrum of deployment contingencies. This subthrust also develops methods of detection, identification and assessment of the potential human health risk from operational chemicals and chemical/biological detection (CBD) agents. Specific deployment and sustainment thrust payoffs include the following:

- Enhanced readiness and capability of logistic support
- Improved accuracy and efficiency of force package development
- Reduced hazardous waste from deployments
- Reduced deployment footprint and support equipment
- Streamlined space/depot maintenance and transportation systems
- Reduced cost of technical data creation and maintenance
- Enhanced predictive tools to assess DoD relevant chemicals, materials, and fuels
- Field development, validation, and transition of capability to detect biological agents in water

Bioeffects and Protection

Predict and Mitigate Mission Degradation

Bioeffects and Protection Subthrusts
- Optical Radiation
- Radio Frequency Radiation
- Biomechanisms and Modeling
- Safe Escape and Impact Protection
- Aircrew Protection
- Sustained Operations
- Spatial Disorientation Countermeasures

The Bioeffects and Protection thrust predicts and mitigates mission degradation due to operational stresses. This thrust area researches the bioeffects of directed energy and provides the database necessary to enable development of effective non-lethal weapons; defines human response to impact, acceleration, and altitude; provides human systems criteria for emergency escape systems and crash protection; develops and demonstrates life support and oxygen systems; and provides technologies to counter spatial disorientation and improve human performance in sustained operations. There are seven subthrusts: Optical Radiation, RF

Radiation, Biomechanisms and Modeling, Safe Escape and Impact Protection, Aircrew Protection, Sustained Operations and Spatial Disorientation Countermeasures.

Optical Radiation includes biological effects of laser radiation that enable RDT&E of non-lethal laser weapons and development of laser eye protection technologies. RF Radiation includes biological effects of RF radiation from acute, chronic, and repeated exposure. Biomechanisms and Modeling includes biological effects of non-lethal DEW applications, development of models for predicting human performance degradation, and the development of warfighter and equipment protection methods. Safe escape and Impact Protection efforts include R&D of human response and tolerance criteria for dynamic environments as well as development and demonstration of advanced crew escape system technologies. Aircrew Protection includes R&D of technologies for aircrew protection from high altitude exposures; research and development of physiological and cognitive response countermeasures to G-induced performance degradation and incapacitation; and development, demonstration, and transition of aircrew life support equipment and advanced oxygen system technologies. Sustained Operations encompasses definition and development of countermeasures for effects of fatigue and circadian disruption due to sustained operations and Global Engagement. Spatial Disorientation Countermeasures investigates the mechanisms of spatial orientation and develops display symbologies and aircrew training procedures to reduce impact of spatial disorientation on flight operations. Specific Bioeffects and Protection Thrust payoffs are:

- Understand, mitigate, and exploit biological effects of optical radiation devices and their countermeasures on personnel
- Create health and safety standards to protect humans and equipment from adverse effects of RF radiation
- Compile bioeffects data for feasibility, utility, and acceptability of non-lethal DEWs
- Develop theoretical predictions of yet-to-be observed effects of directed energy on molecules, tissues, and organs
- Develop passive head/neck protection subsystem for high-speed escape accommodating full aircrew population
- Improve performance and extended operational capacity with 25 percent increase in G tolerance from transparent life support ensemble
- Enhance warfighter fatigue countermeasures that extend operator performance and endurance
- Decrease spatial disorientation by 50 percent in helmet-mounted display symbology for NVG

5.8.4 Relationship of Other S&T to Human Effectiveness ETA

The ETA supports four of the six ITTs and 11 ITTPs as seen in Table 5-9.

The Human Effectiveness ETA S&T strategy can be traced back through the DoD planning process to the fundamental objectives outlined in *Joint Vision 2010*. In FY00, this ETA's programs will support 16 DTOs in three DTAP Panels. Under Project Reliance and the DTAP process, the Air Force currently chairs three of the four sub-areas in the Human Systems Panel. Project Reliance agreements are in place with the Army for chemical defense and biodynamics and with the Army and Navy laser and RF radiation bioeffects. Additional agreements with the Navy focus on warfighter training. The Air Force is an equal player in the tri-service program in toxicology.

Precision Strike ITT
• Real Time Sensor-to-Shooter Operations • Unmanned Combat Air Vehicles
Information Dominance ITT
• Configurable Aerospace Command and Control • Defensive Information Warfare • Consistent Battlespace Picture • Dynamic Command and Control
Training for Warfighting ITT
• Warfighter Operations Center Training* • Simulation and Distributed Mission Training*
Agile Combat Support ITT
• Deployment Planning Command & Control, Reduced Airlift and Sustainment* • Force Protection
** Led by AFRL /HE*

Table 5-9: Human Effectiveness ETA Relationship to Integrated Technology Thrusts and Specific ITT Programs

5.8.5 Human Effectiveness ETA FY25 Vision

The Human Effectiveness ETA far-term vision is aligned with the Air Force core competencies, *Air Force 2025*, and the Air Force Strategic Plan. In integrating air and space, this ETA will provide integrated "train as we fight" technologies, personnel and operator training strategies for exploitation of air and space assets, and human performance models for operator interface trade studies. In ballistic missile and cruise missile defense, directed energy technology protection will be provided for ABL intercept of missiles. Integrated technologies and methods will be available to increase effective use of Air Force Battle Management/Command and Control (BM/C2) assets, acoustic sensors for detection and warning of enemy activity, and cognitive engineering technologies for information processing environment. In the UAV area, directed energy technology will be available for non-lethal SEAD, jammers, and methods. Technologies for human-computer system integration, and human-in-the-loop teleoperations and mission management technologies will also be developed. Directed energy technology for non-lethal expeditionary force protection, force protection from chemical/biological warfare agents, personnel protection from environmental and chemical exposures, and environmental noise constraints for worldwide deployment will be available. Flash-blindness prevention and asset protection will be developed. Safe and effective accommodation of future aircrew population and biodynamics test methods and data for personnel equipment assessment will be developed. In addition, modeling and simulation technologies for human performance evaluations will be created. Finally, logistics systems, deployment planning, and maintenance and diagnostic systems for air and space forces will be developed.

5.9 Materials and Manufacturing

"Materials and Manufacturing Technologies to Sustain Today's Fleet and Enable Tomorrow's Warfighter"

The Materials and Manufacturing ETA goal is to develop materials and processes, manufacturing, airbase, and environmental technologies for today's fleet and tomorrow's warfighters. It also provides systems support to Air Force product centers, air logistics centers (ALCs), and operating commands to solve system-related problems.

The impact of materials technologies is pervasive to all current and future Air Force systems. More importantly, materials and manufacturing capabilities may often represent the limiting factors in system cost, performance, and risk. The challenge is to balance providing better and more affordable material technology support to the current fleet operations and maintenance while developing the material technologies to meet operational challenges for the future Air Force. Whether the challenge is aging Air Force systems or the preparation for next century systems, the vision of this ETA is to provide materials and manufacturing technologies for the entire Air Force, emphasizing technical leadership, technology transition, technology transfer, and systems support.

5.9.1 The Planning Context for Materials and Manufacturing ETA

The Air Force vision of Global Engagement calls for a migration from an air and space force to a space and air force. A key to achieving this vision is affordable space access. This means lighter weight materials to reduce launch costs and in the long run, we believe, it means an aerospace plane that will require lightweight and high temperature materials. Materials are also critical to space operations, protection of space assets, and surveillance systems. Global Engagement also infers global awareness. Advanced sensor materials and manufacturing technologies, along with protection materials to assure freedom of employment, will be required to provide this capability.

The *Joint Vision 2010* Operational Concepts of Dominant Maneuver, Precision Engagement, Full-Spectrum Dominance, and Focused Logistics all impact this ETA area. A critical factor in achieving these operational concepts will be the sustainment of an aging aircraft fleet, including corrosion control, nondestructive evaluation and repair technologies. To maintain Full-Spectrum Dominance materials that can provide protection against growing threats of directed energy will become crucial.

One desired future capability in the *Air Force Strategic Plan* is to provide agile combat support through an Expeditionary Aerospace Force. To support this concept, materials and processes for improved air base technology; such as air inflatable shelter aircraft parking apron stabilization; perimeter defense; and portable, lightweight base support system, will be needed. In addition integrated repair technologies will be necessary to support battle damage, environmental degradation, and other operational damage to aircraft.

The importance of this area was highlighted by a former Undersecretary for DDR&E who singled out materials as one of the top four priorities for DoD S&T. Similarly, the *Air Force 2025* study identified materials as one of the six high leverage technologies important to a large number of high-value system concepts. Other similar studies and plans highlight the importance of advanced materials and processes to sustain today's fleet and enable tomorrow's warfighter.

5.9.2 Investment Strategy for Materials and Manufacturing ETA

In responding to *Air Force 2025* recommendations for a move from air and space to space and air, the strategy in this area is to significantly increase the investment in materials and processes for space. Space technology investment will increase from 21 percent to 28 percent of the total Materials and Manufacturing S&T budget by 2005. The increase will come at the expense of conventional turbine engine performance materials, metals and polymer composite development subthrusts, and aircraft sensor technology. The aircraft technology area will reduce from 34 percent to 25 percent by 2005. To support National Materials Research Council recommendations for Aging Aircraft, the investment in Sustainment will be maintained and will represent 24 percent of the investment in 2005. Non-space sensors and personnel protection continue to be concerns to growing laser threats and technology investment in this area will be maintained at 18 percent. Finally, materials and processes for the area of directed energy are relatively small at the present time. To support Air Force thrusts in this area, the investment will be increased from 3 percent to 5 percent. Table 5-10 summarizes the allocation goals for the investment strategy in this ETA.

AFRL/ML Strategic Investment Application Areas	AFRL/ML S&T Investment Goals	
	FY98	FY05
Space Space Vehicles; Propulsion; Operation; Reentry Vehicle; Structures; Power; Thermal Management; Sensors and Protection; IR & RF Sensors; Space Laser Protection	21%	28%
Sustainment Low Observable Maintenance; Paint; Airbase Technology; Nondestructive Evaluation; Aging Aircraft; High Cycle Fatigue; Pollution Prevention; Systems Support	23%	24%
Aircraft Propulsion; Structures; Subsystems; New Low Observable Materials & Processes; Coatings	34%	25%
Non-Space Sensors and Protection RF Sensor; IR Windows; Eye and Sensor Laser Protection	18%	18%
Directed Energy Space and Non-space Nonlinear Optical (NLO) Materials & Processes for Laser Sources	3%	5%

Table 5-10: The Materials and Manufacturing ETA Strategic Investment Application Area Allocation Goals

5.9.3 FYDP Investment Strategy for Materials and Manufacturing ETA

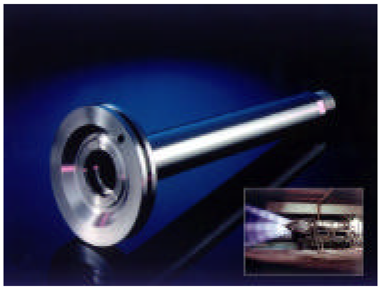
This ETA maintains expertise in thermal protection materials, metallic and nonmetallic structural materials, nonstructural materials, nondestructive inspection, materials used in aerospace propulsion systems, electromagnetic and electronic materials, and laser-hardened materials. The ETA is also responsible for Air Force technology programs that address affordability and the reduction of Air Force system's materials and processing driven, life cycle costs. Planning is accomplished in these technologies and then integrated across three major S&T thrust areas to provide a balanced program directed at customer needs. The Materials and Manufacturing ETA thrusts include (M&P) for Structures, Propulsion, and Subsystems; Survivability and Sensor Materials; and Materials and Processing Technology for Sustainment.

Materials and Manufacturing ETA Thrusts

- Materials and Processes for Structures, Propulsion and Subsystems
- Survivability and Sensor Materials
- Materials and Processing Technology for Sustainment.

This ETA has a fourth thrust - Manufacturing Technology. However, Manufacturing Technology is funded by operational system development funds, with Program Element 78011F, not S&T dollars from Program Elements of Basic Research (6.1), Applied Research (6.2) or Advanced Development (6.3). Because of this, the Manufacturing Technology Thrust is not discussed in this S&T Plan.

Materials and Processes for Structures, Propulsion and Subsystems



Titanium Matrix Composite Actuator Piston

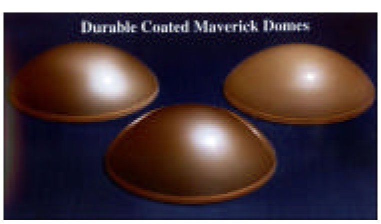
Materials and Processes for Structures, Propulsion, and Subsystems

- Carbon-Carbon and Thermal Protection Materials
- Metallic Materials
- Nonmetallic Structural Materials
- Ceramics Development and Materials
- Nonstructural Materials

The overall objectives are to provide new M&P for piloted aircraft, UAVs, tactical and strategic missiles, launch systems, and satellite structures. Materials under development or transition include metallics, intermetallics, nonmetallics (polymers, ceramics, carbon/carbon) and composites thereof. It also includes nonstructural materials such as solid lubricants, coatings and paints. The Carbon-Carbon and Thermal Protection Materials subthrust will develop materials and processes for multi-use space vehicles. In addition, because of the ability to tailor its modulus and thermal conductivity, it will be developed for space optical platforms, satellite radiators, and solar panels. The Metallic Materials subthrust will provide materials and processes for engines that will provide weight savings for improved thrust-to-weight ratio. In addition high cycle fatigue damage tolerance and life prediction methods will be developed to support engine sustainment issues. The Nonmetallic Structural Materials subthrust will address ultra lightweight composites concepts; high temperature composites to replace aluminum; organic/polymeric conductive materials for LO/smart structures and lightweight batteries; and high quality, thin gauge composites for space structures. The Ceramics subthrust will develop high temperature materials and processes for air and space propulsion systems and for modification of existing engines. Nonstructural materials will develop fluids, lubricants, coatings, aircraft paints, and specialty materials for aircraft and spacecraft. Examples of payoffs in the FY00-FY05 timeframe for this thrust include:

- Organic/polymeric, conductive materials for LO/smart structures, lightweight wiring and batteries, and smart structures
- 40 to 60 percent cost reduction in advanced composite processing
- Improve survivability/penetrability by developing maintainable signature control coatings and LO gap materials
- Corrosion models for life prediction and extension of fleet
- Repair of high temperature radar absorbing materials for engine and exhaust washed structures
- Improved HCF damage tolerance and life prediction methods

Survivability and Sensor Materials



Durable Coatings for Infrared Windows

Survivability and Sensor Materials

- Sensor Materials
- Laser Hardened Materials

The objectives of this thrust are to provide new electronic and EM sensor materials and M&P to enhance survivability and sensor detector capability. This thrust is comprised of two subthrusts: Sensor Materials and Laser Hardened Materials. For Sensors Materials, the objective is to develop high payoff electronic, optical, EO, and magnetic M&P for a wide range of Air Force space, aircraft, missile and ground equipment applications. This includes infrared (IR) detector materials for space; wavelength conversion materials for large aircraft IR countermeasures; semiconductor materials for RF and electronic power applications; IR transparencies for aircraft and missiles; and EO materials for interconnects and satellite communication. The sensor effort is balanced between near-term and mid-term needs. Technologies for current systems will be inserted through upgrades and retrofits. Ultimately, electronics and optical technologies will merge into a single integrated technology for sensing, computing, processing, and communication.

Laser Hardened Materials will increase survivability of aircrews, sensors, aircraft and space systems from DE threats. This effort will provide validated laser hardening technology options to users, developers, and designers of Air Force systems for the protection of aircrew via day and night protective eyewear; tactical and strategic EO sensor hardening. Examples of payoffs for this thrust in the FY00-FY05 timeframe are:

- Alternative focal plane array materials to operate at 40^{o}K for reduced radiator, power and weight
- New optical material classes for protection of eyes, viewing systems and night vision devices
- Affordable high power NLO crystals for laser sources in remote Chem/Bio sensors and countering future mid-IR missile threats.

Material and Processing Technology for Sustainment

Mobile Automated Scanner
Nondestructive Evaluation System

Material and Processing Technology for Sustainment
- Nondestructive Inspection/ Evaluation
- Air Force Field and Aging Systems Support
- Air Base Technology
- Pollution Prevention and Environmental Support

The objective of this thrust is to provide support across all Air Force functional mission areas that will enhance the overall reliability, maintainability and supportability of operational systems. It is comprised of four subthrusts: Nondestructive Inspection/Evaluation (NDI/E) methods, Air Force Field and Aging Systems Support, Air Base Technology, and Pollution Prevention and Environmental Support.

NDI/E methods are essential to ensure optimum quality in the design and production of aircraft, spacecraft, and launch systems. Specifically, this area is developing technologies for LO materials and structures and technologies to inspect and maintain integrity of aging aerospace structures and propulsion systems. Systems Support capabilities, information, and processes are needed to resolve problems in the use of materials or in conducting failure analysis of components. This involves materials databases, handbooks and guidelines for materials technology transition and repair. Enhancement of Airbase Technology is critical to EAF deployment capability. The technologies under development are to provide fire protection and crash rescue, air deployable power generation equipment, environmental controls and shelters; and rapid restoration of operating surfaces. Examples of payoffs for this thrust in the FY00-FY05 timeframe are:

- Enhanced Retirement for Cause (RFC) transitioned to ALCs for turbine engine disk inspection
- Field Level LO verification and structural inspection
- Environmentally compliant corrosion controls, surface preparation and coatings
- Quick-reaction materials engineering support to aging systems product centers, ALCs, MAJCOMs
- Technology for cleaning and surface preparation, paint M&P, and thermal spray coatings
- Air transportable electric power generation and distribution systems; air inflatable shelters; and airfield assessment and repair tools

5.9.4 Relationship of Other S&T Programs to the Materials and Manufacturing ETA

This Materials and Manufacturing ETA provides enabling technologies to four of the six ITTs and 19 of 29 ITTPs. This correlation is seen in Table 5-11.

The Materials and Manufacturing ETA is thoroughly coordinated through the DoD Joint Directors of Laboratories (JDL) Project Reliance and the TARA Materials/Processes Panel and its four subpanels. Through these subpanels the Air Force supports the DTOs and DTAP. The subpanels supported by the Materials and Manufacturing ETA are Civil Engineering and Environmental Quality; M&P for Survivability, Life Extension and Affordability; and Manufacturing Technology. This area is also actively working with the National Materials Advisory Board and National Science and Technology Council to identify critical national M&P issues. This ensures that critical Air Force materials and manufacturing technologies are included in the national investment strategy.

This ETA maintains eight collocates in program offices at the Aeronautical Systems Center, one collocate at the Space and Missile Center, and one at the Air Force Weapons Center. It also chairs Air Force wide working groups such as the coatings technology screening committee. Input from field units and MAJCOMs comes from three field offices operated by AFRL's Materials and Manufacturing Directorate at ALCs. These field offices specifically address corrosion, NDE and composite materials issues. For the development and transition of space technology, collocates are maintained at the Space Vehicles and DE Technical ETAs.

Since The Materials and Manufacturing ETA is broadly based and supports the entire Air Force, it is closely related to many other S&T technology areas.

Space Superiority ITT
• Space Operations Vehicle • Space Based Radar • Space Optics and Laser Technology • Hyperspectral Imaging • Space System Survivability
Precision Strike ITT
• Electro-Optical Countermeasure/ Infrared Countermeasure • Unmanned Combat Air Vehicles • Sensor Protection*
Aircraft Sustainment ITT
• Aging Aircraft Structures* • High Cycle Fatigue • Low Observable (LO) Maintainability* • Turbine Engine Durability
Agile Combat Support ITT
• Deployed Base Support Systems * • Deployment Planning Command & Control, Reduced Airlift & Sustainment • Force Protection* • Active Denial Technology
** Led By AFRL/ML*

Table 5-11. The Materials and Manufacturing ETA Correlation to ITTPs

5.9.5 Materials and Manufacturing ETA FY25 Vision

Long-term planning during the FY00 POM for this ETA was accomplished through five Strategic Investment Application Areas of Space, Sustainment, Aircraft, Sensors and DE. The long-term vision for each of these areas is explained below.

In space, the vision is to enable warfighter exploitation of space with materials and manufacturing technologies for operations, protection, and surveillance. This area will provide an increase in durability and a 20 percent reduction in the cost of thermal protection materials; a 10-fold increase in yields and 90 percent cost reduction of sensor detector materials. Implementation of commercial lean manufacturing practices will become a reality.

The Sustainment area will provide critical materials and manufacturing technologies to affordably sustain fielded and emerging systems and enable EAF operations. Envisioned is a 25 percent reduction of EAF footprint and weight, while reducing the EAF personnel requirement and time by 20 percent. There should also be a 50 percent reduction in the use of toxic materials and a 30 percent reduction in operation and support costs. LO maintenance costs will equal conventional maintenance costs.

In Aircraft, the vision is to ensure continued air superiority with breakthrough materials and manufacturing technologies for propulsion, structures and subsystems. There should be a doubling of fighter aircraft thrust/weight ratio and a 50-90 percent reduction of composite materials cost.

In Sensors, the vision is materials and manufacturing technologies to enable global awareness and assure freedom of employment of all personnel and systems. There will be retrofittable laser protection technologies for EO sensor systems, and affordable day/night all-platform threat-diverse laser protective eyewear for military personnel.

In DE, the vision is to enable full exploitation of DE concepts for strike, protection and deterrence with high power (>10W), high efficiency (~50 percent, mid-IR laser radiation against seeker threats and laser directed energy effects data and protection technology).

6.0 Basic Research

"Dynamic Leading-Edge Research Enabling Revolutionary Warfighter Capabilities"

The Air Force S&T Basic Research Program provides the means for conducting world-class research that enables new technologies and capabilities to be developed and used by the warfighter in order to maintain a technologically superior military force. The program sustains both evolutionary research responsive to recognized needs of current military systems, as well as revolutionary research not specifically focused on current military application, but capable of providing exciting new opportunities for meeting future defense requirements.

The Basic Research Program supports Air Force research efforts comprised of in-house investigations in Air Force laboratories and external activities in academia and industry. The program includes broad-based scientific and engineering basic research in technologies critical to the Air Force mission. These technologies include aerospace structures, aerodynamics, materials, propulsion, power, electronics, computer science, directed energy, conventional weapons, life sciences, and atmospheric and space sciences. The research in these technology areas provides a strong foundation for subsequent advances in the ETAs, and thus the development of new military capabilities and systems.

6.1 The Planning Context for Basic Research

The primary guidance for the Air Force basic research comes from the Defense Basic Research Plan (BRP). This plan is derived from warfighting requirements identified by the Chairman of the Joint Chiefs of Staff as part of *Joint Vision 2010*. The Defense BRP plan identifies 12 basic research areas and identifies specific research objectives for each area. The Air Force Basic Research Program supports research in 10 of these 12 areas: Physics, Chemistry, Mathematics and Computer Science, Electronics, Structural Materials Science, Fluid Mechanics/Dynamics, Solid Mechanics and Structures, Propulsion, Upper Atmospheric Sciences, Space Sciences, Biological Sciences, and Human Performance.

Additional guidance comes from the Air Force SAB's *New World Vistas* report. This report contains recommendations and guidance that address technologies and concepts for the future Air Force emphasizing six capability areas: Global Awareness, Dynamic Planning and Execution Control, Global Mobility in War and Peace, Projection of Lethal and Sub-Lethal Power, Space Operations and People.

6.2 Investment Strategy for Basic Research

As indicated previously, the Air Force investment strategy for basic research is to sustain both evolutionary and revolutionary research. Basic research is invested broadly across the following Air Force-relevant research initiative areas:

- Physics Research
- Solid Mechanics and Structures Research
- Chemistry Research
- Mathematics and Computer Sciences Research
- Electronics Research
- Structural Materials Research
- Fluid Mechanics/Dynamics Research
- Propulsion Research
- Upper Atmospheric Sciences Research

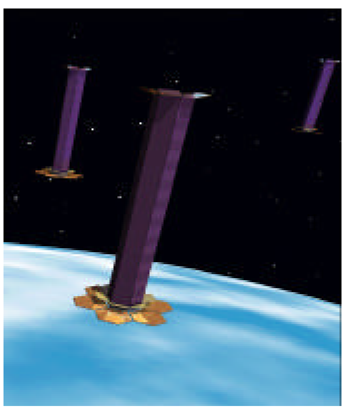
- Space Sciences Research
- Biological Sciences Research
- Human Performance Research

The basic research strategy maintains and strengthens in-house laboratory research capabilities as a foundation for subsequent applied research and systems development activities. AFOSR promotes teamwork and partnerships among DoD laboratories, universities and industry, further leveraging and enhancing research efforts by exploiting knowledge from the international scientific community. The strategy contributes to ensuring the continuing availability of competent young scientists and engineers as well as high-quality research facilities to the Air Force research community through support of university-centered research. The goal of the investment strategy is to be responsible not only to historical threats, but also new threats and global challenges.

6.3 FYDP Investment Strategy for Basic Research

The Air Force Basic Research program encompasses a wide spectrum of research initiatives. The goals of the following areas of the basic research program are to enable the Air Force to enter into the next century as an Expeditionary Air Force. The basic research program establishes technology goals that will advance the state-of-the-art and make possible the payoffs that will be achieved from future Enabling Technology Areas and Integrated Technology Thrust Programs.

Physics Research



A Constellation of Collaborating Microsatellites for Multiple Air Force Missions

Physics Research Programs

- Photonics
- Plasma Physics
- Atomic and Molecular Physics
- Imaging Physics
- Optics

The Physics Research program includes Photonics, Plasma Physics, Atomic and Molecular Physics, and Imaging. The Photonics studies devises and develops lasers and laser arrays with characteristics needed in directed energy, optical information storage and display, wideband communication systems, manufacturing inspection systems and medical diagnostics. Plasma Physics research seeks new knowledge about the complex phenomena of the collective interactions of charged particles with each other and with electromagnetic fields. Atomic and Molecular Physics is the study of the interaction of atoms and molecules related to time and frequency physics and to upper atmospheric modeling. Imaging Physics addresses the theoretical and experimental bottlenecks impeding the exploitation of advanced imaging technologies for the Joint Warfighter. The goals of the Physics Research program include:

- Electronic speeds several orders of magnitude faster than today
- Smaller and more accurate GPS clocks
- Improved modeling capabilities
- Prediction of upper atmospheric processes affecting communications, surveillance, and remote sensing from space
- Recovery of images in the presence of atmospheric turbulence
- Solutions to meet advanced requirements in communication, directed energy, hypersonic drag reduction, and other areas.

Solid Mechanics and Structures Research

Solid Mechanics and Structures Research Programs

- Mechanics of Materials
- Particulate Mechanics
- Structural Mechanics

This area develops a fundamental understanding of the behavior of aerospace materials, structures, and supporting facilities, leading to cost-effective development and safe and reliable operation of superior weapons and defensive systems. Research includes such diverse topics as the micromechanical design of advanced materials, modeling and simulation of the dynamic behavior of aircraft, missiles, and large space structures, and technology integration for the performance and survivability enhancement of these systems. This research will result in expanding the fundamental knowledge base to better understand the mechanics of deformation and damage of aerospace materials and structures. Also, this research will lead to an improved understanding of the aeroelastic and acoustic behavior of airframe and engine structures, and the dynamic behavior of launch vehicles and space structures. The goals of the Solid Mechanics and Structures Research program include:

- Accurate design and life prediction technologies
- Ability to design new materials processing technologies for improved affordability
- Real-time monitoring and self-correction techniques for enhanced system performance
- Understanding of airframe failure and engine stall operational issues.

Chemistry Research

Rocket Propellant Research Supports Continued Access to Space

Chemistry Research Programs

- Surface Science
- Polymer Chemistry
- Molecular Dynamics
- Theoretical Chemistry

The focus is on building the knowledge base required to develop new materials to tailor the properties of materials for Air Force needs and to improve the synthesis of existing materials. The chemistry program investigates effects of chemical and morphological structures on functional and mechanical properties of polymeric materials. The program explores atomic and molecular surface interactions that can limit performance of electronic devices, compact power sources, and lubricant materials and that can cause corrosion. The program also investigates molecular energy release mechanisms and energy storage in metastable molecular systems to foster advances in laser weapons development and new chemical propellants. Research on chemical reactivity and energy transfer also directly impacts the prediction and detection of signatures for surveillance applications and determines the impact of Air Force operations in the atmosphere and space. The goals of the Chemistry Research program include:

- New polymer materials with new properties
- Predictive capabilities for chemical reactivity and energy transfer processes
- Improved aircraft and rocket propulsion system design
- High power chemical lasers
- Energetic materials for propellants and explosives
- Improvements in surface chemistry and thin films

Mathematics and Computer Sciences Research

Airborne Laser for Theater Air Defense

This research focuses on mathematical modeling, simulation, and control of complex systems and provides analytical and computational methods. Topics include effective use of high-performance computers; control of aerospace systems; models and computational tools for the design of aircraft, missiles, or other weapons; robust and efficient algorithms for large scale modeling and simulation of complex systems; communication and information theory; signal processing; artificial intelligence; reliability and maintainability; and the allocation of resources in logistics or operational activities using ideas from optimization and linear programming theories. The goals of the Mathematics and Computer Sciences Research program include:

Mathematics and Computer Sciences Research Programs

- Dynamics and Control
- Physical Mathematics and Applied Analysis
- Computational Mathematics
- Optimization and Discrete Mathematics
- Signals Communication and Surveillance
- Systems and Software
- Artificial Intelligence
- Electromagnetics
- Computational Aerodynamics

- Capability to model complex problems and systems
- Robust feedback controllers for improved aircraft maneuverability and engine stall avoidance
- Control of vibrations and shape of space structures
- Active control of wing camber
- Timely management of information
- Improved target acquisition and recognition
- Detection avoidance

Electronics Research

Research in this area emphasizes electronic devices and systems that enable new Air Force capabilities such as novel space systems, battle information management, countermeasures, sensors, and the MEA concept. The goals are to increase the data and information processing speed of electronic systems, to firmly control their complexity and reliability, and to improve the security and reliability of information and data transmission. The goals of the Electronics Research program include:

Electronics Research Programs

- Joint Services Electronics Program
- Electronic Devices
- Electronic Components and Circuits
- Optoelectronic Information Processing
- Semiconductor Materials
- Electromagnetic Materials
- Quantum Electronic Solids

- Improved transmission bandwidth and data storage
- Increased data and information processing speed
- Lower power consumption, lower noise, higher RF power
- Radiation tolerance
- Greater electronic reliability
- Real-time adaptive signal and image processing capabilities
- Enhanced ability to sense and manipulate observable information

Structural Materials Research

Research focuses on metallic, polymeric, and ceramic and nonmetallic structural materials. Materials research provides the knowledge for improving the performance, cost, and reliability of aerospace structures. Emphasis is on refractory alloys, intermetallics, polymer composites, metal and ceramic matrix composites, and advanced ceramics, such as alumina, silicon carbide, silicon nitride and carbon/carbon. The goals of the Structural Materials Research program include:

Structural Materials Research Programs
- Metallic Structural Materials
- Ceramics and Non-Metallic Structural Materials
- Organic Matrix Composites

- Increased thrust to weight ratio for engines
- Reduced aerospace vehicle weight
- Eliminate materials reliability issues
- Reduced life cycle costs for composites
- Improved vehicle performance and control

Fluid Mechanics / Dynamics Research


Computational Fluid Dynamics Optimizes C-17 Paratroop Deployment

Research involves turbulence prediction and control, unsteady and separated flows, hypersonics and internal fluid dynamics. Research provides an understanding of key fluid flow phenomena, improves theoretical models for aerodynamic prediction and design, and originates flow control concepts and predictive methods to expand current flight performance boundaries. Research also includes the development of computational methods for complex flows, prediction of real gas effects in high-speed flight, control and prediction of turbulence in flight vehicles, propulsion systems, aero-optic applications, the dynamics of unsteady and separated flows, thrust vectoring and high lift concepts associated with enhanced performance and maneuverability, heat transfer and compressor instabilities in gas turbine engines, and flow-structure interactions in both external and internal flows. The goals of the Fluid Mechanics/ Dynamics Research program include:

Fluid Mechanics / Dynamics Research Programs
- External Aerodynamics and Hypersonics
- Turbulence and Internal Flows

- Improved theoretical models for aerodynamic prediction and design
- Flow control concepts
- Expanded flight performance boundaries
- Enhanced maneuverability
- Reduced engine stall

Propulsion Research

The Propulsion Research program conducts research on the propulsion components of all military and space vehicular systems, including aircraft, tactical and strategic missiles, space launch vehicles, space vehicles, and future hypersonic systems. Research is focused on the efficient use of energy on air-breathing rockets. Space propulsion research focuses on thermal management of space-based power and propulsion systems. The goals of the Propulsion research area include:

Propulsion Research Programs
- Space Power and Propulsion
- Combustion and Diagnostics

- Improved thermal management of space power and propulsion
- More efficient utilization of energy in air breathing engines and non-chemical rockets

Upper Atmospheric Sciences Research

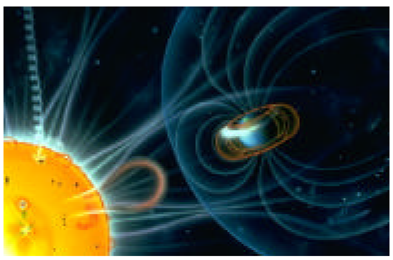
Upper Atmospheric Sciences Research Programs

- Upper Atmospheric Sciences
- Ionospheric Research

Upper Atmospheric Science includes ionospheric and meso-pheric research. This research focuses on the physics, dynamics, and chemistry of processes that determine the structure and variability of the earth's upper atmosphere. Research includes new measurement techniques and the development of models for specifying and predicting space weather and other ionospheric conditions. Emphasis is placed on understanding fundamental upper atmospheric processes and their impacts on optical and IR weapon systems, and on understanding the dynamics and structure of the ionosphere that affect communications and surveillance systems. The goals of the Upper Atmospheric Sciences Research program include:

- Understanding of the upper atmosphere for improved C3I, surveillance, and spacecraft reliability
- Improved ionospheric specification and prediction

Space Sciences Research



Space solar environment consists of electric and magnetic fields, electromagnetic radiation and charged particles

Space Sciences Research Programs

- Space Environment and Solar Activity
- Space Physics

Space Sciences research program provides basic knowledge of the space environment and solar activity for the design and calibration of advanced Air Force systems relevant to operations in and through near-Earth space. The Space environment consists of electric and magnetic fields, electromagnetic radiation, space debris, charged particles, and interplanetary dust that can degrade the performance of Air Force spacecraft and systems. These phenomena can disrupt the detection and tracking of missiles and satellites, distort communications and navigation, and interfere with global surveillance operations. Ultimately, we seek to understand how energy flows from the Sun to the Earth. The goals of the Space Science research program include:

- Improved design and calibration of space systems
- Improved solar and space environment forecasting

Biological Sciences Research

Biological Sciences Research Programs

- Bioenvironmental Sciences
- Chronobiology and Neural Adaptation
- Biomimetic Sensors

The Biological Sciences Research program research is conducted to provide a fundamental understanding of the biological mechanisms regulating human performance, and the response of individuals; and the biological responses of individuals to toxic agents. In order to achieve its objectives, research in the Biological Sciences Program involves the following areas. Bioenvironmental sciences research seeks to understand fundamental mechanisms involved in assessing and predicting the human health and hazards associated with the use of chemicals, lasers and microwave radiation. Chronobiology and Neural Adaptation supports basic research on the circadian timing system, the biology underlying fatigue and performance prediction, the brain processes involved in regulating adaptation to changes-in-state, the neurobiology of attention and the biochemistry of stress. Understanding of these mechanisms will facilitate the development of pharmacological, photonic and behavioral strategies for altering internal pacemaker function and ultimately alleviate the operational performance decrements associated with chronic fatigue, jet lag and night operations. Biomimetic Sensor research seeks to integrate man made sensors with biological sensors or identify new biological materials that may act alone to improve sensory systems for target detection and recognition. The goals of the Biological Sciences Research program include:

- Reduced exposures to hazardous materials.
- Strategies to reduce fatigue due to jet lag and shift-work
- Reduced loss of life and aircraft due to stress, inattention and lack of vigilance
- Biomimetically enhanced sensors.

Human Performance Research

Model perception and cognition for improved human performance

Human Performance Research Programs

- Perception and Cognition
- Sensory Systems

The Human Performance Research program conducts research in human performance to support personnel readiness and technology development for Command and Control, and information systems. This program deals with several aspects of human performance in order to attain its objectives. Research in Perception and Cognition seeks to improve testing for personnel selection and classification, and the development of technologies to support both adaptive teams for Command and Control, and the future workstations with embedded intelligent tutoring. Sensory Systems vision research seeks to improve the effectiveness of visual displays, and camouflage and to create novel systems for automated processing of image data. Hearing research supports the need for secure error-free voice communication and improved human interface technologies that take advantage of automatic speech recognition and virtual environments. Multisensory integration research is critical for the development of uninhabited air vehicles. Perceptual and Cognitive research supports the need for selection and classification of personnel, improved instruction and training, and expert performance in an environment of increasing cognitive workload. The goals of the Human Performance Research program include:

- Improved effectiveness of visual displays
- Error-free communication
- Improved personnel instruction and training
- Improved Command and Control
- Improved personnel selection and classification

6.4 Relationship of Other S&T to Air Force Basic Research

The Air Force Basic Research program provides the foundation for future Air Force ETAs and ITTs. Figure 6-1 shows the relationship of the Basic Research program to the ITTs and the ETAs.

Integrated Technology Thrusts							Enabling Technology Areas								
Space Superiority (Section 4.1)	Precision Strike (Section 4.2)	Information Dominance (Section 4.3)	Aircraft Sustainment (Section 4.4)	Agile Combat Support (Section 4.5)	Training for Warfighting (Section 4.6)	Basic Research Areas	Space Vehicles (Section 5.1)	Directed Energy (Section 5.2)	Information (Section 5.3)	Sensors (Section 5.4)	Munitions (Section 5.5)	Propulsion (Section 5.6)	Air Vehicles (Section 5.7)	Human Effectiveness (Section 5.8)	Materials and Manufacturing (Section 5.9)
●	●	●		●		Physics	●	●	●	●		●	●		●
●	●		●	●		Solid Mechanics and Structures	●				●	●	●		●
●	●	●	●			Chemistry	●	●	●	●	●	●	●		●
●	●	●	●	●	●	Mathematics and Computer Sciences	●	●	●	●	●	●	●	●	●
●	●	●		●		Electronics			●	●					●
●			●			Structural Materials	●	●				●	●		●
●			●			Fluid Mechanics/Dynamics						●	●		
●	●	●	●	●		Propulsion	●					●	●		
●	●			●		Upper Atmospheric Sciences	●		●						
●						Space Sciences	●								
		●		●	●	Biological Sciences								●	●
		●		●	●	Human Performance			●					●	

Figure 6-1: AFRL Basic Research Relationship to
AFRL ITTs and to AFRL ETAs

The DDR&E, other services, DARPA, and BMDO jointly plan and coordinate DoD's basic research efforts through the Defense Committee on Research (DCOR). Air Force participation in DCOR assures that Air Force research is integrated with the remainder of defense research. All projects are further coordinated through the Reliance process to harmonize efforts, eliminate duplication, and ensure the most effective use of funds. All technology areas are subject to long-range research planning and technical review by tri-Service scientific planning groups that interface and support the DTAP process.

Two international offices (Asian Office of Aerospace Research and Development and the European Office of Aerospace Research and Development) identify foreign technological capabilities and accomplishments that can be applied to Air Force needs. They also provide liaison with members of the international scientific and engineering community and encourage open communication with Air Force scientists and engineers.

6.5 Basic Research FY25 Vision

AFOSR's role is to track the leading edge of technology in order to avoid technological surprise. It is conceivable that the Air Force will be involved in areas of research different from what is currently being pursued, but this research will still fit within the broad technology categories of physics, mathematics, etc.

It is impossible to predict what the leading edge of technology will be in 25 years, but it is expected that current research, as described below, will have come to fruition by that time.

Long-range goals involve plasma physics research to meet requirements in the areas of: communications, radar, low observables, directed energy weapons, hypersonic drag reduction, electronic warfare, chem/bio detection and materials processing. Interatomic interactions will be used to make GPS type clocks smaller and more accurate, improve data and modeling capabilities; and permit prediction of upper atmospheric processes affecting communications, surveillance, reconnaissance and targeting from space. Unconventional imaging methods to recover images in the presence of atmospheric turbulence will be available for both active and passive imaging systems. Microelectromechanical systems (MEMS) will be exploited for aerodynamic control and smart aerospace systems. Development of multifunctional structures as opposed to integrating separate subsystems will be used to create what is currently a notional weapon system. Nanotechnology and architecture will be available for space use and power generation capabilities. Lightweight, efficient solar-powered chemical lasers will be available for space-based applications. Novel propellants will be available that can double the payloads or halve the cost of access to space. New coatings chemistries will be used to address corrosion abatement for metal surfaces. Vapor lubrication chemistries will be addressing high temperature (supersonic) engine operations such as Joint Expendable Turbine Engine Concepts (JETEC).

New radiation-hardened electronic technologies will be available for space system applications. Broadband, tunable IR sources suitable for defense against seeker missiles will be used on air and space platforms. Advanced solid-state (semiconductor) RF power sources will be developed for high frequency electronic systems. Uncooled electronic devices suitable for space applications will be developed. Lightweight space structures and launch vehicles will be common. Advanced materials will provide global reach without refueling. Low cost lightweight materials will reduce launch costs. Improved materials will permit non-destructive inspection and evaluation.

Tactical and strategic decision makers will have timely and relevant assessments of the aerospace environment to optimize the performance of global surveillance, reconnaissance, targeting, and strike systems. Space environment forecasting support will be available for operations of piloted space-based reconnaissance and combat vehicles and space-based high-energy laser systems. Human performance modeling research will enable realistic constructive simulation for distributed, simulation-based training for warfighters, including models that incorporate effects of fatigue and individual differences in cognitive abilities. Low-cost, reconfigurable synthetic task environments developed to support these research efforts will also support simulation-based acquisition in which concepts are rapidly developed and tested in terms of their effects on human performance prior to system acquisition. Research on sensory capacities and multi-sensory integration will enable competent human performance in environments and will support human factors design for information and control environments.

Acronym Glossary

A

ABL – Airborne Laser

ACS – Agile Combat Support

ADT – Active Denial Technology

AEOS – Advanced Electro-Optical Sensor

AFLRP – Air Force Long-Range Plan

AFMC – Air Force Materiel Command

AFMPP – Air Force Modernization Planning Process

AFOSR – Air Force Office of Scientific Research

AFRL – Air Force Research Laboratory

AFSP – Air Force Strategic Plan

AFSPC – Air Force Space Command

AFTO – Air Force Technology Objective

ALC – Air Logistics Center

AMRAAM – Advanced Medium Range Air – to – Air Missile

AMTI – Airborne Moving Target Indication

APPG – Annual Planning and Program Guidance

APSI – Aircraft Propulsion Subsystem Integration

ASAT – Anti-Satellite

ATD – Advanced Technology Demonstration

ATEGG – Advanced Turbine Engine Gas Generator

ATPP – Advanced Turbo Propulsion Plan

ATR – Automatic Target Recognition

B

BM/C2 – Battle Management/Command and Control

BMDO – Ballistic Missile Defense Office

BRP – Basic Research Plan

C

CAD – Computer – Aided Design

CBD – Chemical Biological Detection

CCE – Combined Cycle Engines

CEM – Computational Electromagnetics

CM – Countermeasures

COTS – Commercial-Off-The-Shelf

CRDA – Cooperative Research and Development Agreement

CSAF – Chief of Staff of the Air Force

C2 – Command and Control

C2I – Command, Control and Intelligence

C3I – Command, Control, Communication and Intelligence

C4 – Command, Control, Communication and Computers

C4ISR - Command, Control, Communication, Computers, Intelligence, Surveillance and Reconnaissance

D

DAC – Dynamic Aerospace Command

DARPA – Defense Advanced Research Projects Agency

DCOR – Defense Committee on Research

DC2 – Dynamic Command and Control

DDR&E – Director of Defense Research and Engineering

DE – Directed Energy

DEW – Directed Energy Weapon

DMT - Distributed Mission Training

DoD – Department of Defense

DoT – Department of Transportation

DSTAG – Defense Science and Technology Group

DTAP – Defense Technology Area Plan

DTO – Defense Technology Objective

DUS&T – Dual Use Science and Technology

D2 – Disrupt and Degrade

E

EAF – Expeditionary Aerospace Force

EM – Electromagnetic

EMD – Engineering, Manufacturing and Development

EO – Electro-Optical

EOCM – Electro-Optical Countermeasures

ETA – Enabling Technology Area

EW – Electronic Warfare

F

FAA – Federal Aviation Administration

FOPEN – Foliage Penetrating

FYDP – Future Year Defense Plan

F2T2EA – Find, Fix, Track, Target, Engage and Assess

G

GBL – Ground–Based Laser

GEO – Ground Electro-Optical

GIB – Global Information Base

GMTI – Ground Moving Target Indication

GPS – Global Positioning System

H

HCF – High Cycle Fatigue

HEDM – High-Energy Density Materials

HMT/D – Helmet Mounted Tracker/Display

HPM – High Power Microwave

HSI – Hyperspectral Sensor Imaging

HTS – High Temperature Superconductivity

HTSM – Hard Target Smart Munitions

I

IHPRPT – Integrated High Payoff Rocket Propulsion Technology

IHPTET – Integrated High Performance Turbine Engine Technology

IR – Infrared

IRCM – Infrared Countermeasures

ISR – Intelligence, Surveillance, Reconnaissance

ITT – Integrated Technology Thrust

ITTP – Integrated Technology Thrust Program

J

JDAM – Joint Direct Attack Munition

JDL – Joint Directors of Laboratories

JETEC – Joint Expendable Turbine Engine Concept

JFACC – Joint Forces Air Component Commander

JSF – Joint Strike Fighter

JTDE – Joint Technology Demonstrator Engine

JWCO – Joint Warfighter Capability Objectives

JWSTP – Joint Warfighter Science and Technology Plan

K

L

LADAR – Laser Detection and Ranging

LEO – Low Earth Orbit

LIDAR – Light Detection and Ranging

LITE – Laser Integration Technology

LO – Low Observable

LOCAAS – Low Cost Autonomous Attack System

M

MAP – Mission Area Plan

MAV – Military Aerospace Vehicle

MEA – More Electric Aircraft

MEI – More Electric Initiative

MEMS – Microelectromechanical Systems

MIS – Modular Insertion Stage

MMW – Millimeter Microwave

MOA – Memorandum of Agreement

MPP – Modernization Planning Process

M&P – Materials and Processes

M&S – Modeling and Simulation

N

NBC – Nuclear, Biological, Chemical

NDE – Nondestructive Evaluation

NDI – Nondestructive Inspection

NLO – Nonlinear Optical

NRO – National Reconnaissance Office

NVG – Night Vision Goggles

NWV – New World Vistas

O

OSD – Office of the Secretary of Defense

P

PE – Precision Engagement

POM – Program Objective Memorandum

P3I – Preplanned Product Improvement

Q

R

RDT&E – Research Development Test and Evaluation

RF – Radio Frequency

RFC – Retirement for Cause

RLV – Reusable Launch Vehicle

R&D – Research and Development

S

SAB – Scientific Advisory Board

SAF – Secretary of the Air Force

SBIR – Small Business Innovation Research

SBL – Space-Based Laser

SBR – Space-Based Radar

SEAD – Suppression of Enemy Air Defenses

SMP – Strategic Master Plan

SMV – Space Maneuver Vehicle

SOR – Starfire Optical Range

SOV – Space Operations Vehicle

SSB – Small Smart Bomb

STI – Space Technology Institute

STOW – Synthetic Theater of War

S&T – Science and Technology

T

TAC-

TARA – Technology Area Review and Assessment

TIP – Technology Investment Plan

U

UAV – Unmanned Air Vehicle

UCAV – Unmanned Combat Air Vehicle

V

WXYZ

WMD – Weapons of Mass Destruction