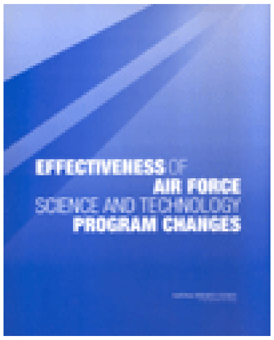

Effectiveness of Air Force Science and Technology Program Changes

Committee on Review of the Effectiveness of Air Force Science and Technology Program Changes, National Research Council

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EFFECTIVENESS OF AIR FORCE SCIENCE AND TECHNOLOGY PROGRAM CHANGES

Committee on Review of the Effectiveness of Air Force Science and Technology Program Changes

Air Force Science and Technology Board

Division on Engineering and Physical Sciences

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Preface

The scope, content, and conduct of science and technology (S&T) activities in the Department of Defense (DoD) are subject to virtually continuous review by internal and external advisory groups. In the U.S. Air Force, S&T is the purview of the Air Force Research Laboratory (AFRL), which both contracts to industry and academia and conducts research in-house for current and future Air Force needs.

The management of a government S&T endeavor has always been challenging and is certainly no less so today. The challenges facing AFRL are similar to those facing other DoD laboratories. They include renewing the technical staff (an aging cadre not necessarily matched to tomorrow's problems); balancing investment in traditional threats and technical areas with that in emerging and future ones; and serious budget pressures from competition with near-term service needs such as readiness and modernization. Numerous advisory committees have studied these issues in depth over the years, each voicing concerns and suggesting possible improvements. In response to such concerns, the Air Force instituted a number of changes in the structure and management of its S&T program starting in about 1999.

The Committee on Review of the Effectiveness of Air Force Science and Technology Program Changes was formed by the National Research Council (NRC) under a U.S. Air Force contract in response to legislation mandating the study. Its overall charter was to review the effectiveness of the Air Force S&T program, in particular actions the Air Force has taken to improve management of the program over the last 3 years. Given the short time since the Air Force instigated these changes and for their effects to have become manifest, this review should be considered a work in progress. The approach taken by the committee was to build on the work of previous studies. Since the legislation required a relatively rapid response, the scope of the work was necessarily limited. Specifically, the technical content of the S&T program was beyond the committee's purview.

To gather data, the committee reviewed the previous studies and heard from congressional staff, the Air Force and its Scientific Advisory Board, the Army, the Navy, and the Defense Advanced Research Projects Agency during open meetings. The prior studies and congressional concerns centered on four issues central to S&T: advocacy and visibility, planning, the workforce, and the level of investment. This report and its recommendations are organized around these general topics.

The committee greatly appreciates the support and assistance of NRC staff members James C. Garcia, Deanna Sparger, and Daniel E.J. Talmage, Jr., and consultant Norm Haller, in the preparation of this report.

Alan H. Epstein, *Chair*
Committee on Review of the Effectiveness of Air Force Science and Technology Program Changes

Acknowledgment of Reviewers

This report has been reviewed in draft form by individuals chosen for their diverse perspectives and technical expertise, in accordance with procedures approved by the National Research Council's Report Review Committee. The purpose of this independent review is to provide candid and critical comments that will assist the institution in making its published report as sound as possible and to ensure that the report meets institutional standards for objectivity, evidence, and responsiveness to the study charge. The review comments and draft manuscript remain confidential to protect the integrity of the deliberative process. We wish to thank the following individuals for their review of this report:

Frederick T. Andrews, Bell Communications Research, Inc.,
Joseph F. Janni, Air Force Maui Optical and Supercomputing Site,
Hans M. Mark, University of Texas,
Robert F. Naka, CERA, Inc.,
Malcolm R. O'Neill, Lockheed Martin Corporation,
Sheila E. Widnall, Massachusetts Institute of Technology, and
George O. Winer, Georgia Institute of Technology.

Although the reviewers listed above have provided many constructive comments and suggestions, they were not asked to endorse the conclusions or recommendations, nor did they see the final draft of the report before its release. The review of this report was overseen by Alexander H. Flax, consultant. Appointed by the National Research Council, he was responsible for making certain that an independent examination of this report was carried out in accordance with institutional procedures and that all review comments were carefully considered. Responsibility for the final content of this report rests entirely with the authoring committee and the institution.

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Acronyms

ACC	Air Combat Command
ACTD	advanced concept technology demonstration
AFA	Air Force Association
AFIT	Air Force Institute of Technology
AFMC	Air Force Materiel Command
AFOSR	Air Force Office of Scientific Research
AF RAP	Air Force Resource Allocation Process
AFRL	Air Force Research Laboratory
AF SAB	Air Force Scientific Advisory Board
AFSOC	Air Force Special Operations Command
AFSPC	Air Force Space Command
ALC	Air Logistics Center
AMC	Air Mobility Command
APPG	annual planning and programming guidance
ATC	applied technology council
ATD	advanced technology demonstration
AWACS	airborne warning and control system
CC	commander
CFC	critical future capability
CFG	critical future goal
ConOps	concept of operations
CSAF	Chief of Staff of the Air Force
DARPA	Defense Advanced Research Projects Agency
DAWIA	Defense Acquisition Workforce Improvement Act of 1990
DDR&E	Director Defense Research and Engineering
DMSP	Defense Meteorological Satellite Program
DoD	Department of Defense
DoDI	Department of Defense instruction
DoE	Department of Energy
DPG	defense planning guidance
DSB	Defense Science Board
DSP	Defense Support Program
EHF	extremely high frequency
EMD	engineering and manufacturing development
FMR	financial management regulation

FY	fiscal year
FYDP	Future Years Defense Program
GAO	General Accounting Office
GPS	Global Positioning System
HQ	headquarters
IPT	integrated product team
JDAM	Joint Direct Attack Munition
MAJCOM	major command
MDA	Missile Defense Agency
MILCON	military construction
MILSATCOM	Military Satellite Communications
NASA	National Aeronautics and Space Administration
NDAA	National Defense Authorization Act
NPOESS	National Polar-orbiting Operational Environmental Satellite System
NRAC	Naval Research Advisory Committee
NRC	National Research Council
OMB	Office of Management and Budget
OSD	Office of the Secretary of Defense
O&M	operations and maintenance
PBR	President's budget request
PE	program element
P.L.	Public Law
POM	Program Objectives Memorandum
PPBS	Planning, Programming, and Budgeting System
R&D	research and development
RDT&E	research, development, test, and evaluation
SAB	Scientific Advisory Board
SAE	service acquisition executive
SAF/AQ	Assistant Secretary of the Air Force for Acquisition
SAF/AQR	Deputy Assistant Secretary of the Air Force for Science, Technology, and Engineering
SAF/AQRT	Science and Technology Division
SBIR	Small Business Innovation Research
SBIRS	Space Based Infrared System
SECAF	Secretary of the Air Force
SECDEF	Secretary of Defense
SES	senior executive service
SPO	system program office
STO	short-term objective
S&E	scientist and engineer
S&T	science and technology
TEO	technology executive officer
TOA	total obligational authority
TRL	technology readiness level
TUT	targets under trees
USAF	United States Air Force
USD/AT&L	Under Secretary of Defense for Acquisition, Technology, and Logistics
WCMD	Wind Corrected Munition Dispenser
WMD	weapons of mass destruction
WSCP	Weapon System Capability Plan
WTA	Warfighter Technology Area

Executive Summary

INTRODUCTION AND OVERVIEW

Under mandate of Section 253, Study and Report on Effectiveness of Air Force Science and Technology Program Changes, of the Fiscal Year 2002 National Defense Authorization Act (Public Law 107-107; U.S. Congress, 2001), the U.S. Air Force contracted with the National Research Council (NRC) to conduct the present study. In response, the NRC established the Committee on Review of the Effectiveness of Air Force Science and Technology Program Changes—composed of academics, active and retired industry executives, former Air Force and Department of Defense (DoD) civilian executives, and retired general officers with acquisition and science and technology (S&T) backgrounds. The committee was to review the effectiveness of the Air Force S&T program and, in particular, the actions that the Air Force has taken to improve the management of the program in recent years in response to concerns voiced in numerous study reports and by Congress. The committee's principal charter was to assess whether, as a whole, the changes put in place by the Air Force since 1999 are sufficient to assure that adequate technology will be available to ensure U.S. military superiority (see Box ES-1).

The committee conducted four open meetings to collect information from the Air Force and its Scientific Advisory Board (SAB), the U.S Navy, the U.S. Army, and DoD. A great many factors influence any judgment of the S&T program's sufficiency in supporting future warfighter needs; these factors include threat assessment, budget constraints, technology opportunities, workforce, and program content. Given the relatively short time available for this study and considering the detailed reviews conducted annually by the SAB, the technical content of the S&T program was necessarily beyond the committee's purview. Rather, the committee focused on S&T management, including areas that have been studied many times, in depth, by previous advisory groups (e.g., Defense Science Board [DSB], SAB, Air Force Association [AFA], Naval Research Advisory Committee [NRAC], and NRC). Besides addressing technical content, those prior studies and congressional concerns highlighted four overarching S&T issues: advocacy and visibility, planning, workforce, and investment levels. In response, the Air Force instituted changes in S&T management. This study should be considered a review of Air Force work in progress, because there has been only a relatively short time (for an organization working to annual budget cycles) for the effects of these changes to be manifested.

The Air Force S&T budget total is set from the top down (i.e., allocated by Air Force leadership in competition with other demands, such as readiness, modernization, and operations—a competition held against the backdrop of dramatic reductions in overall Air Force funding during the 1990s). As a competitor for scarce resources against shorter-term, often more pressing concerns, S&T's success in the budget negotiations is dependent upon the Air Force leadership's perception of the value that S&T can bring to meeting the needs of the Air Force. This perception is dependent on both the program's true value and the effectiveness with which that value is communicated to Air Force leadership.

Long-term funding stability is critical to successful S&T. Elements that must be present for success in the

BOX ES-1
Statement of Task

The NRC is requested to conduct a study to determine how changes to the Air Force science and technology program implemented during the past two years affect the future capabilities of the Air Force. The NRC will:

1. Independently review and assess whether such changes as a whole are sufficient to ensure the following:

    A. That concerns about the management of the science and technology program that have been raised by the Congress, the Defense Science Board, the Air Force Scientific Advisory Board, and the Air Force Association have been adequately addressed.
    B. That appropriate and sufficient technology is available to ensure the military superiority of the United States and counter future high-risk threats.
    C. That the science and technology investments are balanced to meet near-, mid-, and long-term needs of the Air Force.
    D. That the Air Force organizational structure provides for a sufficiently senior level advocate of science and technology to ensure an ongoing, effective presence of the science and technology community during the budget and planning process.

2. In addition, the study shall independently assess the specific changes to the Air Force science and technology program as follows:

    A. Whether the biannual science and technology summits provide sufficient visibility into, and understanding and appreciation of, the value of the science and technology program to the senior level of Air Force budget and policy decisionmakers.
    B. Whether the applied technology councils are effective in contributing the input of all levels beneath the senior leadership into coordination, focus, and content of the science and technology program.
    C. Whether the designation of the commander of the Air Force Materiel Command as the science and technology budget advocate is effective to assure that an adequate budget top line is set.
    D. Whether the revised development planning process is effective to aid in the coordination of the needs of the Air Force warfighters with decisions on science and technology investments and the establishment of priorities among different science and technology programs.
    E. Whether the implementation of section 252 of the Floyd D. Spence National Defense Authorization Act of Fiscal Year 2001 (as enacted into law by Public Law 106-398; 114 Stat. 1654A-46) is effective to identify the basis for the appropriate science and technology program top line and investment portfolio.

SOURCE: U.S. Congress (2001).

budgeting process are (1) communication of the value of a program (which depends on the skill, influence, and message of the communicator); (2) relevance of the program to the warfighter (which comes from planning); and (3) the quality of the program (for which quality of the workforce is a major determinant). Thus, the committee's focus and recommendations concentrate on these issues. They are all areas in which the Air Force has worked in recent years to improve its S&T capabilities.

The committee's views are contained in many findings and recommendations. They are summarized in the following four sections: "S&T Investment," "Workforce," "Planning" (S&T Planning, and Development/Capability Planning), and "Communications: Advocacy and Visibility." The complete findings are in Chapters 2 and 3.

S&T INVESTMENT

The proper level of Air Force S&T investment and how to ensure it have been issues of some debate. Overall, top-line funding for S&T is set by the allocation of funds in competition with elements such as readiness and modernization.

The committee holds firmly to the view that stability in funding is fundamental to ensuring S&T success. While funding stability is important to any endeavor—operations, development, and modernization—its importance grows with the time span of the effort. Thus, it is most important to the S&T program, which has the longest time horizon for return on investment. The S&T program consists of three elements: basic research (6.1), applied research (6.2), and advanced technology development (6.3), the latter consisting of two parts—critical experiments and advanced technology demonstrations (ATDs).[1] Stability of funding is especially important at the 6.1 and 6.2 levels and is also important in order to maintain the infrastructure necessary for the critical experiments fraction of the advanced technology development (6.3) budget. Investment in ATDs can and should be based on an understanding of the anticipated technological needs of the programmed and planned acquisition programs.

Air Force S&T funding needs and opportunities are rapidly expanding, suggesting that an increased level

[1]The designations 6.1, 6.2, and 6.3 represent the DoD budget activities corresponding to basic research, applied research, and advanced technology development, respectively.

of investment in S&T to support Air Force missions could be productively applied to help ensure the long-term security and military superiority of the nation. Supporting factors include these: new and emerging threats clearly evident after the atrocity of September 11, 2001; results of the Section 252 review[2] that identified significant unfunded opportunities and challenges; new classes of systems moving toward the field, such as directed energy weapons; reduced S&T investments by others (such as the National Aeronautics and Space Administration [NASA]) from which the Air Force historically benefits; and new opportunities afforded by scientific advances (such as in the nano, biological, and ever-expanding information sciences). Emphasis on new threats and new opportunities should not always be at the expense of ongoing research.

This committee believes that stability, in fact as well as in prospect, is as important as a specific (reasonable) S&T funding level. Considering, within the context of stability as a governing principle, the questions of what the proper level of S&T funding is and how to get there, the first question is ill posed; elaboration is required. The Air Force leadership (and its DoD and congressional oversight) address the question of what the Air Force S&T budget should be in a particular year given competing budget priorities. The question implied in the committee's statement of task is whether the Air Force S&T program is sufficient to counter future high-priority threats and ensure military superiority. Previous reports examining S&T funding use still other criteria. Addressing the question of the S&T funding in a substantive, quantitative manner would require a study far beyond the scope of this effort.

While lacking an analysis-based, quantitative assessment as discussed above, it is possible to examine the issue of funding level through the second question—how to get there. In both the fiscal year (FY) 1999 and FY 2000 National Defense Authorization Acts, Congress said that 2 percent real growth per year over the period covered by the Future Years Defense Program (FYDP) should be the objective for defense S&T funding, especially Air Force S&T funding (U.S. Congress, 2000, 2001). The Air Force has not met this objective. The committee believes that an approach of 2 percent annual real growth over the 6-year period of the FYDP has merit. This increase is modest in terms of annual growth, manageable by the Air Force Research Laboratory (AFRL) and, in the committee's judgment, realizable within the pressures facing the Air Force budget. Over the 6-year period of the FYDP, a 2 percent real growth rate would bring the S&T budget to about the average level of the past two decades. This increase would provide funding to pursue new requirements and opportunities beyond those that could be funded if existing programs were trimmed.

Recommendations for the detailed distribution of a funding increase are beyond the scope of this study. Broadly speaking, however, the committee suggests that growth should be balanced among near-, mid-, and far-term opportunities. The growth should apply to the sum of 6.1 and 6.2 budgets (with AFRL leadership determining the relative growth between the two) and to the 6.3 total. The growth in 6.1 and 6.2 funds is commingled here because the committee believes that there is more of a continuum between 6.1 and 6.2 than is generally acknowledged and that it is the responsibility of AFRL leadership to determine the relative growth between the two. The committee notes, however, that the 6.1 budget has suffered considerable atrophy over the past decade, especially compared with that for 6.2. The 6.3 advanced technology demonstrations (ATDs) are most effective in supplying the latest technology when they are completed near the time that the technology is needed by an acquisition program. As a result, the allocation between critical experiments and ATDs should be modulated according to the demands of anticipated acquisition programs.

Stability is also influenced by the S&T budget fraction that is under direct Air Force control. AFRL is the organization responsible for execution of the Air Force S&T budget, but Air Force S&T funds comprise only 60 percent of the AFRL budget. The remainder is provided by other sources, such as the Defense Advanced Research Projects Agency (DARPA). Outside funding augments the Air Force's S&T funding, providing leverage for AFRL. However, there is a danger in over-reliance on such funding, since these resources are outside the Air Force planning processes and are subject to external organizations' shifts in priorities.

Recommendation. The committee recommends that the Air Force S&T budget be grown, in accordance with the investment objective stated by Congress. When that level is achieved, every effort should be made to keep it there, thereby assuring future S&T investment stability.

The balance between Air Force S&T and other

[2]Air Force S&T planning review mandated by Section 252 of P.L. 106-398, the FY 2001 National Defense Authorization Act.

sources of AFRL funding should be monitored with regard to impact on the stability of the total S&T program and the maturation and transition of the technology needed for acquisition programs.

WORKFORCE

A successful S&T enterprise must be staffed by talented and motivated people. The quality of the military and civilian S&T workforce is as important as the level of the S&T budget. Indeed, a quality workforce is a prerequisite for effective use of S&T funding. With new classes of threats to national security and the increasing importance of system-level and multidisciplinary technologies, the need for an agile Air Force S&T enterprise has never been greater.

DoD research laboratories generally and the Air Force laboratory specifically have been plagued by endemic workforce challenges. Problems within the DoD scientist and engineer (S&E) workforce have been aggravated in the past 15 years by policies that have adversely affected personnel and resulted in a crisis in the Air Force S&E workforce, both civilian and military. The Air Force has been acutely aware of this problem for a number of years and has attempted remedial actions. The committee urges that the process and progress of these efforts be carefully reviewed to ensure that on the basis of a sufficiently comprehensive analysis the right steps are being taken and that future actions are implemented consistently over the years and are measured on the basis of carefully derived metrics.

One major hurdle that the Air Force and other DoD enterprises have encountered is that many personnel problems are beyond the authority of a local commander to remedy. For example, under current rules, the service laboratories simply cannot compete for top-notch talent. One reason is the long delay now required to formalize employment offers. A person who is greatly interested in a job with a government laboratory may understandably be unwilling to wait many months for approval when the private sector can provide an immediate offer of employment. Unless personnel constraints such as this are addressed immediately, the service laboratories face a downward spiral from which recovery will be extraordinarily difficult.

A key step toward alleviating this situation would be for Section 1114 of the FY 2001 National Defense Authorization Act (Public Law [P.L.] 106-398) (U.S. Congress, 2000) to be implemented.[3] Because this issue transcends the Air Force, such direction would have to apply to all of the service laboratories and would therefore be effective only if directed by the Secretary of Defense. The committee believes that this is a situation in which national security concerns merit direct involvement of the Secretary of Defense.

The S&E workforce problems did not materialize overnight, and fixing them will require time, a dynamic understanding of requirements, career management of the military and civilian S&E workforce, continuing infusion of resources, and, most importantly, long-term commitments by the current and future Air Force secretaries and chiefs of staff. The committee strongly believes that these workforce actions must be taken.

Recommendations. The Secretary of Defense should immediately direct the implementation of the provisions of Section 1114 of the FY 2001 National Defense Authorization Act (P.L. 106-398) so that Department of Defense laboratory directors have the ability to shape their workforces. The Air Force Secretary and Chief of Staff should ensure rapid execution of these provisions.

The Air Force should conduct a comprehensive review of requirements for military and civilian S&E-trained people across the Air Force, including laboratories and system program offices, and establish a system for long-term management of the S&E workforce.

PLANNING

The quality and utility of the Air Force S&T program is as dependent on the planning process as it is on the execution. As described below, the Air Force plans its technology programs on many levels through formalized processes.

S&T Planning

Recognizing the importance of comprehensive planning, Congress mandated "a review of the long-term challenges and short-term objectives" of the Air Force S&T programs (Section 252, FY 2001 National De-

[3]Section 1114 of the FY 2001 National Defense Authorization Act (P.L. 106-398) amended Section 342 of the FY 1995 National Defense Authorization Act (P.L. 103-337), by giving the Secretary of Defense the authority, without approval by the Office of Personnel Management, to conduct personnel demonstration projects in DoD laboratories.

fense Authorization Act, P.L. 106-398). The Air Force complied with requirements of this act by involving some 300 people in a planning process in 2001 that identified six long-term challenges and eight short-term objectives. The annual resources that would be needed to execute the S&T that this process identified total about twice the current S&T funding level.

Participants agreed that this process was an effective aid in defining a candidate investment portfolio. Additional refinements beyond the Section 252 planning methodology are needed to influence the S&T portfolio, and many possibilities for refinements exist.

The applied technology councils (ATCs) provide a powerful mechanism for reviewing the 6.3 S&T activity. The 6.2 activities would also benefit from a similar annual review that engaged outside stakeholders such as the warfighters and Air Force major commands (MAJCOMs). Such a review should include activities marginally above and below the nominal budget limit.

Recommendations. The Air Force should take advantage of the framework provided by Section 252 of the FY 2001 National Defense Authorization Act as an important step in its overall long-term S&T planning process. Further legislation is not required.

For future use, the Air Force should refine the FY 2001 National Defense Authorization Act Section 252 framework to develop the long-term plan that the Air Force sees as the overarching concern. In doing this, the Air Force should seriously consider the many suggestions offered by this committee, but giving special attention to the following: (1) implementing the "lessons learned" that were briefed to the committee by personnel from the office of the Deputy Assistant Secretary of the Air Force for Science, Technology, and Engineering; (2) fully incorporating the planning process into the planning, programming, and budgeting system, specifically with regard to timing and the application of fiscal constraints, especially for long-term challenges; (3) revising the planning categories to cover mid-term challenges (5 to 15 years) and long-term challenges (15 years and beyond); and (4) aligning the framework to the current Air Force strategic planning process by using the ConOps Task Forces framework in lieu of the short-term objectives framework.

The Air Force Research Laboratory should institute a review process for 6.2 and 6.3 critical experiments that engages the warfighters and major commands.

Development/Capability Planning

"Development planning" is the definition of broad requirements in support of the eventual procurement of a system (aircraft, spacecraft, munitions, and so on) and its operation in the system-of-systems that now comprises a modern warfighting organization. In recent years, one of the weakest aspects of Air Force planning has been the dearth of development (or, using current Air Force terminology, "capability") planning. This was a strong process in the Air Force through the 1980s, but it was subsequently zero funded by Congress without Air Force challenge. More recently Congress has reauthorized development planning, and the first steps toward restoring it are under way in the Air Force.

Establishing a development (capability) planning organization with development teams and planning personnel is mandatory for improving the planning of future systems. While the Air Force now recognizes the need for this process, it is a long way from having viable development/capability planning. The shortage of S&E personnel is a major worry today, but the shortage of qualified system-of-systems analysts and concept designers with a strong systems engineering background is more acute. Attracting these skilled people requires a funded budget line item, special job positions, and high-level leadership (e.g., a leader with experience reaching back to earlier development planning). The organization should be led by a general officer or senior executive service (SES) civilian and staffed with a cadre that includes personnel with operational and S&T experience. Such a group is necessary if there is to be an effective capability plan leading to innovative future warfighting systems that rapidly and fully exploit our expanding technology base.

Recommendation. The Air Force should reconstitute a strong, crosscutting development/capability planning organization staffed by experienced individuals with broad backgrounds and in-depth expertise (combined operational and S&T experience would be highly desirable).

COMMUNICATIONS: ADVOCACY AND VISIBILITY

Effective communication of the value of S&T is important to ensure an adequately funded, healthy program. To this end, the Air Force made three major changes to improve the advocacy and visibility of the S&T program.

The first change was the designation of the Air Force Materiel Command (AFMC) commander (a four-star general) as the S&T advocate. In the past, this was the role of the AFRL commander (a two-star general). This change is positive in terms of both increased visibility and stronger advocacy of the S&T program—both to internal stakeholders (the Air Force) and to external stakeholders (other services, the Office of the Secretary of Defense [OSD], and Congress). Actual effectiveness can be measured over time by metrics such as (1) the level and trend of the S&T budget relative to that of prior years and to the Air Force budget and (2) the amount of technology transitioned from the laboratory to Air Force acquisition programs.

The second change was the instigation of "S&T Summits," day-long meetings of top Air Force leadership at which the entire time is spent reviewing S&T. The summits have been effective in improving dialogue among S&T people, the MAJCOM commanders, and key staff personnel. While it is still too early to determine the summits' longevity, there are grounds for concern, since the December 2002 summit was canceled and may not be rescheduled. Summits are demanding in terms of preparation time and attendance time for senior leaders, but they are worth the effort. Indeed, the scope of this effort could be expanded by instituting similar exchanges between the S&T advocate and other constituencies, including OSD, other services, and key congressional members and staff.

The third change involves the applied technology councils. Some of the most important coordination is among the S&T community (which develops technology), the product centers (which use technology to develop systems), and the warfighters (who use the systems). The focus of these activities is the transition of technology out of the laboratory, into systems, and out to the field. ATCs are one mechanism instituted to make available technology visible to the users and to effect its orderly transition. The ATC process has already been very beneficial and should be continued. However, this process has not yet been codified in an Air Force regulation, although one had been drafted (as of late December 2002).

While to many the value of S&T to the Air Force is self-evident, to many others the lessons of history could profitably be told. One approach to this endeavor would be to task the Air Force history community to document, for reading throughout the Air Force, the technological history of the enablers of current major Air Force capabilities (such as stealth and precision munitions). Another approach would be the development of case studies that could be used at the Air War College to enhance the curriculum for all Air Force mid-level officers. The objective would be to provide future Air Force planners and leaders with an appreciation of the link between S&T and operational military capabilities.

Recommendations. The important S&T Summit process should be continued on an annual basis, arranged over time to cover the full range of S&T categories. The summits should be aligned to best influence the budget process.

The applied technology council process, along with Weapon System Capability Plans, should be continued and codified by regulation.

The commander of the Air Force Materiel Command should continue as the S&T advocate. A mechanism should be instituted for the S&T advocate to brief the S&T plan to and receive feedback from the combatant commanders, the Office of the Secretary of Defense, other service personnel, key congressional staff, and members of Congress, if practical; this mechanism should include the possibility of briefing the results of the S&T Summits as well.

1

Introduction

BACKGROUND

This study was mandated by Congress in the National Defense Authorization Act for Fiscal Year 2002 (P.L. 107-107), Section 253: Study and Report on Effectiveness of Air Force Science and Technology Program Changes (see Appendix A). Section 253 requested that the National Research Council (NRC) conduct a study to determine how changes that the Air Force had implemented to its science and technology (S&T) program during the previous 2 years responded to concerns about the program that had been raised by Congress, the Defense Science Board (DSB), the Air Force Scientific Advisory Board (SAB), and the Air Force Association (AFA). Section 253 also requested that the NRC determine how those changes affected the future capabilities of the Air Force (U.S. Congress, 2001).

In recent years, there have been numerous concerns expressed, studies conducted, and recommendations made pertinent to the Air Force S&T program. Congress has expressed its concerns in a series of national defense authorization acts. The DSB, SAB, AFA, NRC, and Naval Research Advisory Committee (NRAC) have conducted studies and issued reports. (These are summarized in Appendix E.) A synthesis of the concerns and recommendations from these studies and reports yields a list of five overarching issues with respect to the Air Force S&T program. (See Table 1-1.)

TABLE 1-1 Synthesis of Concerns and Recommendations

	Issue				
Concern Raised by:	S&T Investment Levels and Balance	S&E Workforce	S&T and Development Planning	S&T Advocacy and Visibility	Technology Availability
Congress	X	X	X	X	X
DSB	X	X			X
AF SAB	X	X	X	X	X
AFA	X	X	X	X	
NRC	X	X		X	X
NRAC	X	X		X	

The five areas in Table 1-1 correspond to the main concerns or issues identified in Section 253 of P.L. 107-107 and in the statement of task for this study (see the section "Statement of Task," below). The areas are these:

- S&T investment levels and balance (Statement of Task Part 1.C);
- The S&E workforce (within Statement of Task Part 1.A);
- S&T and development planning (Statement of Task Parts 2.D, 2.E, and within Part 1.A);
- S&T advocacy and visibility (Statement of Task Parts 1.D through 2.C); and
- Technology availability, or content of the Air Force S&T program (Statement of Task Part 1.A).

AIR FORCE RESPONSE TO CONCERNS

During the initial meeting for this study, the Air Force presented its view of the background for the study and described actions that the Air Force had taken to respond to the concerns raised by Congress and others (Schneider, 2002a,b). The Air Force identified 16 reports that had been published from January 1999 through January 2002 that expressed concerns and provided recommendations about the Air Force S&T program. In these reports, the Air Force found numerous comments and 202 recommendations, ranging from "quick and easy" to implement, to "difficult and time consuming." Within the group of 202 recommendations, the Air Force found some to be seemingly contradictory.

Of the 202 recommendations, the Air Force found 28 that it felt did not apply to this study. Of the remaining 174, the Air Force believed that the Secretary of Defense was the primary action party for 52 of them and that the Secretary of the Air Force was the primary action party for 122. The Air Force concluded its background presentation to the study committee by stating that "the Air Force has heard the concerns and is addressing those concerns" (Schneider, 2002a).

In describing the actions that it had taken to address concerns, the Air Force used five overarching areas (not exactly the same as, but similar to the list described above): the S&E workforce, visibility and advocacy of S&T, technology availability, S&T planning, and balanced investment. For each of these five areas, the Air Force then described specific actions that it had taken and changes that it had made to address these concerns. These actions and changes included holding "S&T Summits," creating applied technology councils (ATCs), designating the Air Force Materiel Command commander (AFMC/CC) to be the Air Force's S&T advocate, reinstituting development planning, and conducting the S&T planning review required by Section 252 of the FY 2001 National Defense Authorization Act (P.L. 106-398) (see Appendix B).

STATEMENT OF TASK

The Deputy Assistant Secretary of the Air Force for Science, Technology, and Engineering sponsored this study. The statement of task for the study is as follows (see Appendix A):

> The NRC is requested to conduct a study to determine how changes to the Air Force science and technology program implemented during the past two years affect the future capabilities of the Air Force. The NRC will:
>
> 1. Independently review and assess whether such changes as a whole are sufficient to ensure the following:
>
>   A. That concerns about the management of the science and technology program that have been raised by the Congress, the Defense Science Board, the Air Force Scientific Advisory Board, and the Air Force Association have been adequately addressed.
>
>   B. That appropriate and sufficient technology is available to ensure the military superiority of the United States and counter future high-risk threats.
>
>   C. That the science and technology investments are balanced to meet near-, mid-, and long-term needs of the Air Force.
>
>   D. That the Air Force organizational structure provides for a sufficiently senior level advocate of science and technology to ensure an ongoing, effective presence of the science and technology community during the budget and planning process.
>
> 2. In addition, the study shall independently assess the specific changes to the Air Force science and technology program as follows:
>
>   A. Whether the biannual science and technology summits provide sufficient visibility into, and understanding and appreciation of, the value of the science and technology program to the senior level of Air Force budget and policy decisionmakers.
>
>   B. Whether the applied technology councils are effective in contributing the input of all levels beneath the senior leadership into coordination, focus, and content of the science and technology program.
>
>   C. Whether the designation of the commander of the Air Force Materiel Command as the science and technology budget advocate is effective to assure that an adequate budget top line is set.
>
>   D. Whether the revised development planning process is effective to aid in the coordination of the needs of the Air Force warfighters with decisions on science and technology investments and the establishment of priorities among different science and technology programs.
>
>   E. Whether the implementation of section 252 of the Floyd D. Spence National Defense Authorization Act of Fiscal Year 2001 (as enacted into law by Public Law 106-398; 114 Stat. 1654A-46) is effective to identify the basis for the appropriate science and technology program top line and investment portfolio.

The NRC Committee on Review of the Effectiveness of Air Force Science and Technology Program Changes recognized that the tasks listed above encourage unequivocal "yes" or "no" answers; however, the committee judged that unequivocal answers would lack consideration of a number of factors. First, they would imply unequivocal forecasts about what is required for military superiority, the nature of future high-risk threats, how to counter those high-risk threats, and how technology could, given certain changes by the Air Force, unfold to ensure all of those outcomes. Second, military superiority does not depend on S&T alone, as unequivocal answers to the statement of task questions might imply, but instead on successfully balancing, within the reality of constrained resources, the risks among (1) today's readiness and ongoing operations, (2) modernizing to meet tomorrow, and (3) investment in S&T as the basis for modernizing the "day after tomorrow." Such forecasts and balances are at least implicit in the funding requests contained in the President's budget request (PBR) each year, but they can never be unequivocal.

The committee found Statement of Task Question 1.B to be particularly troublesome in this regard. Ensuring that the Air Force has appropriate and sufficient technology to counter future threats in the post-September 11, 2001, era is perhaps more difficult than at any time in the past. The reasons are multifaceted. First, terrorism, the possible development and use of weapons of mass destruction (WMD) by rogue nations, and more widespread availability of means to deliver WMD all increase the diversity of the threats our country faces and make the nature of such threats more uncertain. Second, as stated above, the funds available to support the development of countering technologies are constrained by limited total Air Force funding in the context of a high operational tempo, the necessity of renewing stockpiles of expended weapons (readiness), replacing or upgrading aging weapons systems and infrastructure (modernization), and adapting to the changing nature of 21st-century warfare (transformation). Third, both threats and countering technologies are more numerous and more complex—as are all aspects of modern living—as the result of the inexorable advances of scientific discovery and engineering applications.

Even without the totality of these complexities, attempts to evaluate the effectiveness and adequacy of programs of long-term research have always met with substantial difficulty. The results of long-term research will not be available in time to be useful for currently approved projects, and those projects for which the results of long-term research could be helpful have not yet been approved or fully defined. Moreover, since S&T funding amounts to less than 2 percent of the overall Air Force program but is made up of perhaps a thousand or more individual tasks and programs, it is not conducive to regular, comprehensive, in-depth reviews by senior Air Force leadership.

Within the resources available to it, the committee faced the same challenge in conducting a comprehensive, in-depth review of the Air Force S&T program. The committee believed that it could not definitively answer the question posed by Statement of Task Question 1.B ("That appropriate and sufficient technology is available to ensure the military superiority of the United States and counter future high-risk threats"). However, the availability of appropriate, sufficient, and flexible technology is significantly affected by several factors that the committee could address. Those factors include the following:

1. The level and stability of overall S&T funding;
2. The S&T investment balance to meet near-, mid-, and long-term needs;
3. The flexibility of the S&T program to aggressively pursue new and evolving challenges and opportunities without disrupting ongoing, productive programs;
4. The organization for advocacy of S&T;
5. The quality and quantity of the S&E workforce;
6. The effectiveness of the link between the S&T programs and the programmed and anticipated acquisition programs provided by development planning and other means; and
7. The methodology for S&T planning and the visibility into the planning both by those who advocate the other major elements of the Air Force program (the Major Commands) and by those who integrate the overall Air Force program (the Air Force Corporate Structure).

These factors are addressed in the chapters that follow.

In summary, the committee did not attempt to provide unequivocal answers. Instead, it attempted to assess the changes that the Air Force had made to its S&T program and to judge whether those changes addressed past concerns about the Air Force S&T program and whether those changes were for the better or the worse. In other words, had the Air Force moved its S&T program in the right direction?

STUDY APPROACH

To conduct this study, the NRC formed an independent committee of persons with knowledge and expertise relevant to the study issues. Concise biographical sketches of the committee members are provided in Appendix C. Over a 7-month period, the committee gathered data and information through meetings with persons involved in Air Force and Department of Defense (DoD) S&T planning, budgeting, and execution and through review of relevant reports and other documents. Appendix D contains a list of the presentations made to the committee by guest speakers.

ORGANIZATION OF THE REPORT

Chapter 2 addresses the level of the Air Force's total S&T investment (top line) and the balance of that investment. It responds to statement of task Parts 1.A and 1.C and addresses factors 1 through 3 listed above.

Chapter 3 addresses the areas of the S&E workforce, S&T planning, development planning, and S&T program advocacy and visibility. Included in its discussion, Chapter 3 addresses specific changes that the Air Force has made in these areas. It responds to statement of task Parts 1.A and 1.D, and 2.A through 2.E and addresses factors 4 through 7, listed above.

The appendixes provide supplementary information, as described in the report.

2

Air Force S&T Investment Level and Balance

INTRODUCTION

Primary among the concerns raised by Congress and other groups reviewing the Air Force S&T program has been the appropriateness of the S&T investment level (see Appendix E). Since this study was tasked with evaluating (1) the adequacy with which the Air Force has addressed the concerns voiced in these reports and (2) the sufficiency of the technology investment, the committee examined the Air Force S&T investment level and balance.

After a brief program description, this chapter addresses the level of the Air Force's total S&T investment (top line) and the balance of that investment—the latter from both an internal perspective (near- versus mid- versus long-term S&T) and an external perspective (the balance of S&T investment with other elements of the Air Force program).

AIR FORCE S&T PROGRAM DESCRIPTION

Planned and executed by the Air Force Research Laboratory (AFRL), the Air Force S&T program has three elements—basic research, applied research, and advanced technology development. These are often referred to by the designation of the applicable DoD budget activities: 6.1, 6.2, and 6.3, respectively. AFRL further divides advanced technology development (6.3) into critical experiments and advanced technology demonstrations (ATDs). In addition to funding appropriated specifically for Air Force S&T, AFRL also receives funding from other sources (e.g., DARPA). Some of this outside funding is used for advanced concept technology demonstrations (ACTDs).

The 6.2 tasks often flow from advances in the 6.1 program, 6.3 critical experiments from the 6.2 program, and ATDs from critical experiments. ATDs are specifically planned to lead to efforts that have been programmed or planned by the Air Force and that are either preliminary to an acquisition program or are part of an acquisition program. In some cases, the products of the technology programs can be immediately applied in response to operational needs, as in the case of technology demonstrations that have a residual operational capability. Usually, however, the results of a technology program must be transitioned into an acquisition program to complete the development, production, and deployment of sustainable products to the operational forces.

The act of transitioning technology to an acquisition program is often not directly controlled by the Air Force. Rather, the mechanism for technology transition to acquisition programs is largely through system architecture decisions and design choices made by industry in response to performance requirements or the need for new capabilities, as stated by the Air Force.

In planning its S&T program, the Air Force describes its approach as twofold. First, AFRL works closely with the operational users and acquisition centers to identify the highest-priority technology needs (operational pull or challenges). Second, AFRL develops a broad range of S&T that promises to provide new and improved capabilities (technology push or opportunities). Ultimately, the tasks and programs planned to address technology needs and to provide technology push compete for constrained funding.

AFRL is often called on to address issues facing the

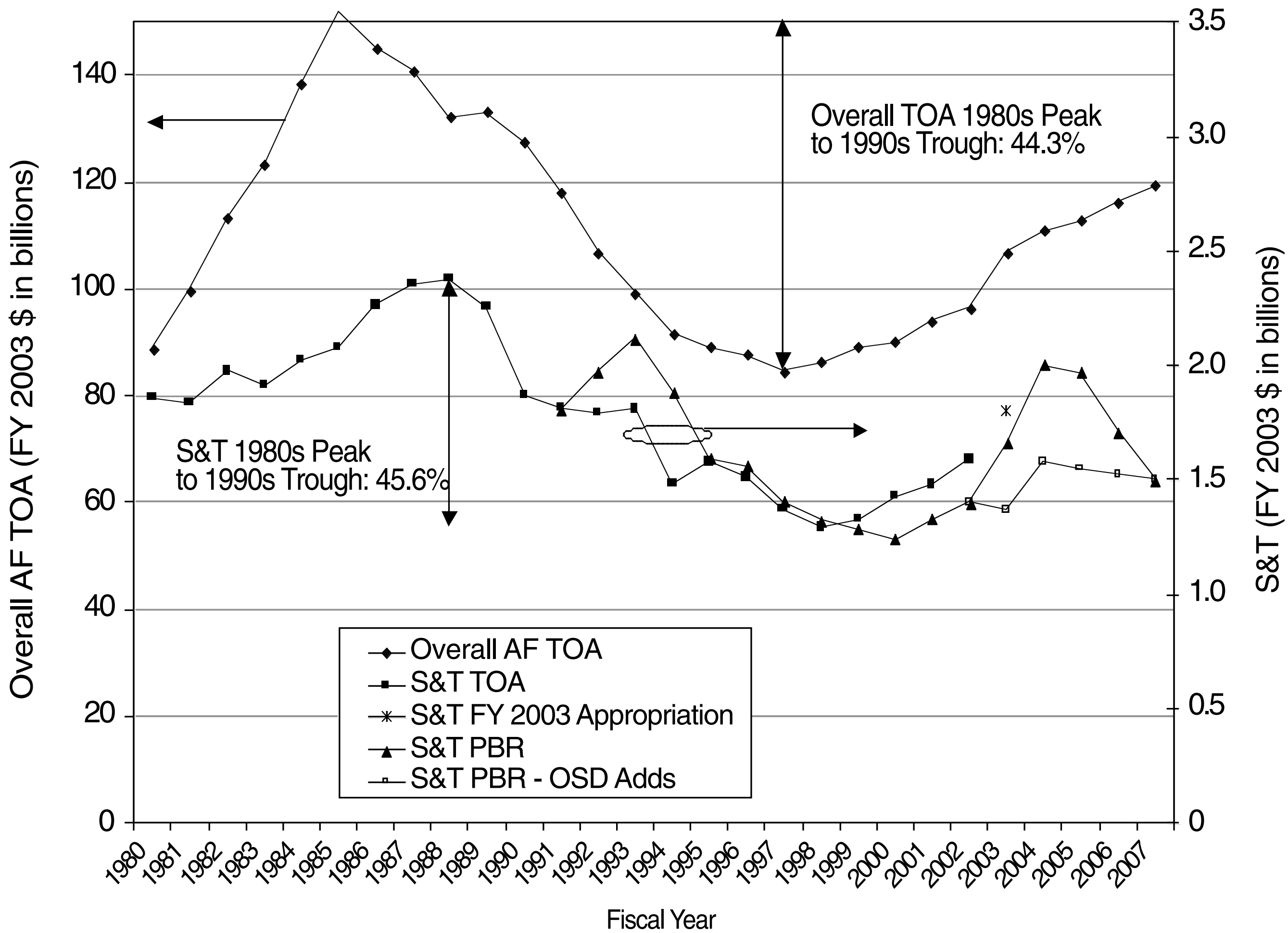


FIGURE 2-1 Air Force TOA for S&T and the Air Force as a whole (S&T TOA through FY 2002, appropriation for FY 2003, DoD FYDP for FY 2004 through FY 2007, all in FY 2003 constant dollars). SOURCES: Schneider, 2002b (Chart 44); DoD, 2002a; Hunsberger, 2002; Jones, 2002; Borger, 2002; U.S. Air Force, 2002.

Air Force to which AFRL's science and engineering expertise apply. Also, the Air Force S&T program often provides benefits that extend beyond Air Force programs. However, although it makes other important contributions, the primary purpose of the Air Force S&T program and of AFRL is to provide the technology base needed by Air Force acquisition (modernization) programs.

AIR FORCE S&T INVESTMENT LEVEL

This section addresses the issue of setting the Air Force S&T top line. In doing so, it first provides a historical look at Air Force S&T funding. It then addresses the balance of the Air Force S&T investment with other elements of the Air Force program.

Air Force S&T Funding History

Figure 2-1 shows the estimate, as of the fall of 2002, for the overall annual funding for Air Force S&T from FY 1980 through FY 2007 in FY 2003 constant dollars.[1] In the figure, "S&T TOA" is the Air Force's total obligational authority (TOA) for S&T resulting from the annual appropriation act plus subsequent funding actions. The version available to the committee accompanied the FY 2003 President's budget request (PBR)

[1]Unless otherwise stated, all funding data shown in this report that were not cited in the relevant source in FY 2003 constant dollars have been inflated/deflated using the ratio of current year to constant year TOA for the applicable title as reported in DoD (2002a).

and defined the DoD baseline through FY 2007. For comparison, the overall Air Force TOA is also shown.

As Figure 2-1 shows, S&T funding peaked during the strategic modernization program of the 1980s. The average during the 1980s was about the same as the long-term average of $2.1 billion. In the 1990s, however, S&T TOA generally declined to a post–World War II low of about $1.3 billion in FY 1998, a decline of about 46 percent from the maximum in the 1980s.[2] S&T was up in FY 1998 through FY 2002, primarily as a result of congressional increases over the PBR. This trend continued in FY 2003 when Congress increased the funding by $147 million, or 9 percent over the PBR. Actual S&T TOA for any fiscal year has usually ended up being less than the appropriation for that fiscal year as a result of funding actions by DoD or Congress, at times by more than $100 million (Robertson, 2002).

In the FY 2003 PBR, the Office of the Secretary of Defense (OSD) made additions to the Air Force S&T program for the Transformational Wideband Military Satellite Communication (MILSATCOM) program and Special Programs.[3] Congress then reduced part of the funding and moved the remainder to non-S&T budget activities.[4] The data at the right side of Figure 2-1, which show the estimate in the future years both with and without that planned for Transformational Wideband MILSATCOM,[5] provide an indication of the range of possible budget variations. The result is considerable uncertainty in out-year funding for S&T funding in general and for the two programs added by OSD in particular.

Figure 2-2 provides a closer look at the right-hand side of Figure 2-1. Starting in FY 1991, it contrasts the S&T TOA through FY 2002 and the FY 2003 appropriation with the PBR to Congress. The TOA reflects the changes made to the PBR by Congress in the appropriation and any subsequent actions by Congress or

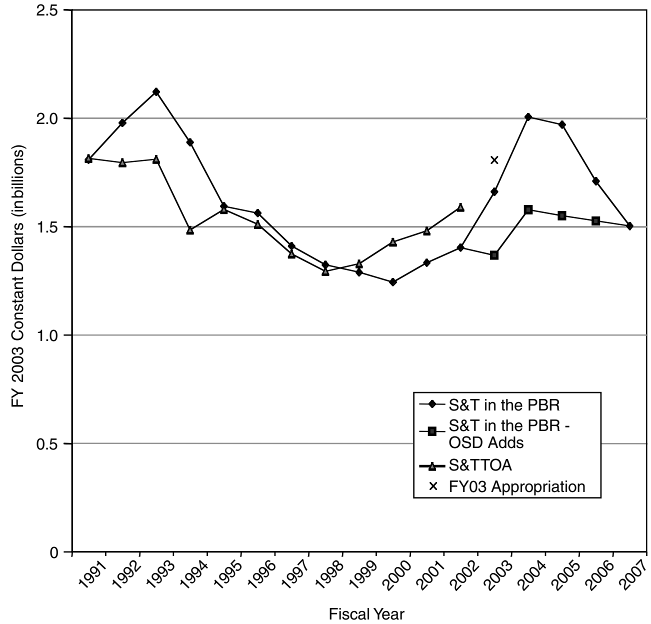


FIGURE 2-2 Air Force S&T TOA compared with the PBR. SOURCES: Hunsberger, 2002; Jones, 2002; Borger, 2002; DoD, 2002b; U.S. Air Force, 2002.

DoD. The FY 2003 appropriation indicates the changes made by Congress to the PBR for that year. No congressional action has yet been taken on the PBR beyond FY 2003. The PBR reflects Air Force management of its S&T program, perhaps modified by OSD and Office of Management and Budget (OMB) oversight.

Early in the period shown in the figure, the funds appropriated by Congress were usually lower than the PBR. In the latter part of the period, the PBR, which presumably reflects the Air Force's recommendations, requested increased S&T for the Air Force but not as fast as Congress increased the annual appropriation. This trend continued for the FY 2003 appropriation (though, as noted above, the final S&T TOA may be lower than shown). The lower curve on the right side of Figure 2-2 shows the estimate without the OSD additions discussed above in FY 2003 and without the Transformational Wideband MILSATCOM in the following years.[6] Without the additions, the requested funding for Air Force S&T would have declined in FY 2003 compared with that in FY 2002. Preliminary in-

[2]Some earlier reports (AFA, 2000, and NRC, 2001a) showed the funding time series starting in FY 1989 using data that were different from those provided to this committee for FY 1989 (about $2.8 billion versus the $2.3 billion shown here). Though the trend in the 1990s is the same, the slope in the early 1990s is dramatically different.

[3]"Special Programs" are highly classified programs with special access required.

[4]Similar issues arose and similar outcomes resulted when Discoverer II and Space Based Laser were moved to S&T in the FY 2000 proposed budget—see AFA (2000), p. 18.

[5]The planned S&T funding beyond FY 2003 for the Special Programs was not available to the committee.

[6]As noted above, the planned S&T funding beyond FY 2003 for the Special Programs was not available to the committee.

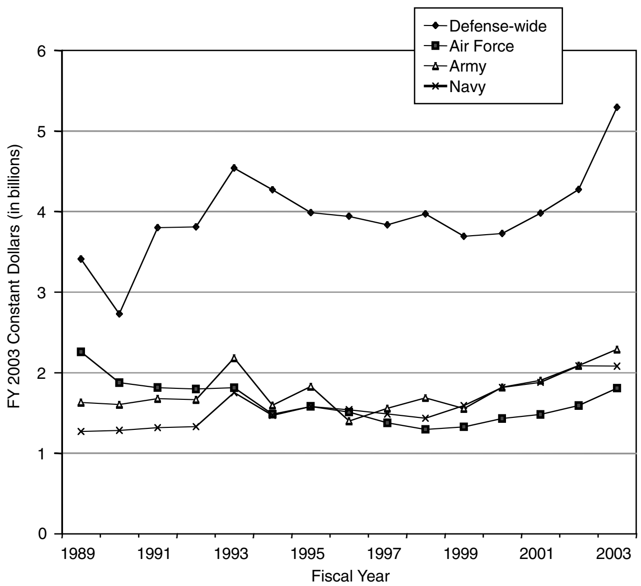


FIGURE 2-3 Comparison of service and Defense-wide S&T TOA (TOA through FY 2002, appropriation for FY 2003). SOURCES: Hunsberger, 2002; DoD, 2002a; Jones, 2002.

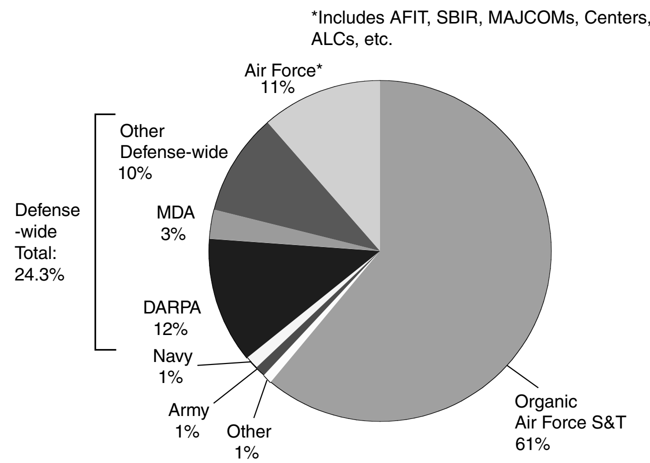


FIGURE 2-4 Sources of total funding for AFRL in FY 2002. SOURCE: Legault, 2002.

formation suggests that the FY 2004 and FY 2005 PBRs will be down compared to the 2003 level. It is clear from the above data that the Air Force S&T funding history resembles a roller coaster, a condition under which program planning and execution are extremely taxing.

Some of the reports referred to in Chapter 1 discuss the Air Force S&T funding in relation to that of the other services. Figure 2-3 compares the funding among the services along with that for Defense-wide S&T (i.e., for the Defense Advanced Research Projects Agency [DARPA], the Missile Defense Agency [MDA], and so on).[7] The sum of the constituents shown in the figure is the total DoD S&T, for which the appropriations are almost $11.5 billion for FY 2003.

As Figure 2-3 shows, Air Force S&T funding in FY 1989 was higher than that for the other services, fell by the early 1990s to about the same level as the other services, and has been lower than the other services since then. On the other hand, Defense-wide S&T funding, which also declined in the mid-1990s, has grown substantially in the past 3 years.

Substantial funds in addition to those specifically identified earlier as Air Force S&T go toward addressing Air Force technology needs. As shown in Figure 2-4, Air Force S&T in FY 2002, as an example, accounted for just over 60 percent of the funds available to AFRL (which is about the same as in FY 2000 when it was 59 percent) (AFRL, 1999).

As shown in Figure 2-4, about one-quarter of AFRL's total funding came from the Defense-wide S&T program (up slightly from just under 23 percent in FY 2000) (Neighbor, 1999), with DARPA being the largest such source (although down slightly from 14 percent in FY 2000). The remainder came from Air Force non-S&T funds, the other services, and non-DoD sources. In addition, other parts of the Defense-wide S&T program may ultimately help to satisfy Air Force technology needs. Still other parts of Defense-wide S&T may fund programs that the Air Force would be directed to fund were it not for the Defense-wide programs. The Air Force can leverage its S&T investment with funds made available through the risk-taking, innovative culture of DARPA and other Defense-wide programs, but at the same time, it should be kept in mind that the direction of such work is controlled to a significant degree by the organizations that transfer the funds to AFRL.

In addition to the S&T supported by AFRL, Air Force acquisition programs benefit from industry Inde-

[7]In addition to DARPA and MDA, other elements of Defense-wide S&T include the Chemical and Biological Defense Program, Defense Information Systems Agency, Defense Special Weapons Agency, Defense Threat Reduction Agency, Joint Chiefs of Staff, Office of the Secretary of Defense, and the Uniformed Services University.

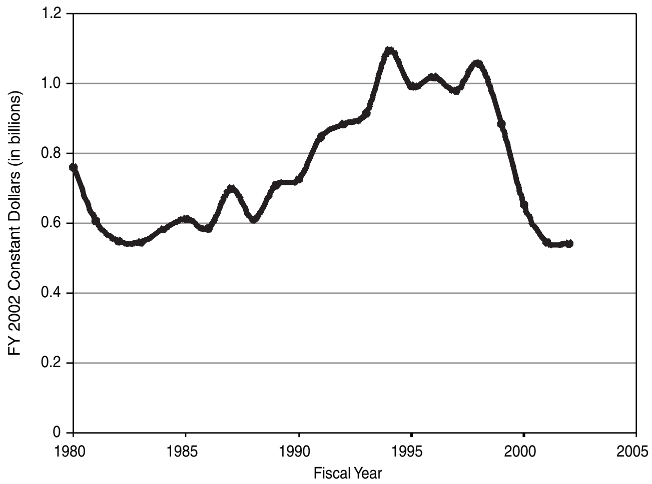


FIGURE 2-5 President's budget requests for NASA aeronautical technology. (These amounts do not include government personnel or facilities.) SOURCE: NASA Office of Aerospace Technology, 2003.

pendent Research and Development funds, which are funded by allowable indirect (overhead) costs on certain DoD contracts. Also, technology developments funded by other federal (such as Department of Energy [DoE] and NASA), commercial, and international efforts often support Air Force needs and may be adapted to Air Force needs in its S&T and acquisition programs.

In a broad sense, the Air Force and NASA share stewardship of the nation's aerospace future, since their activities dwarf those of the other services and non-DoD agencies. Consider, for example, aeronautics, which encompasses all of the disciplines needed for flight, including avionics, software, communications, automation, human factors, navigation, control, propulsion, structures, materials, aerodynamics, and systems engineering. Together, the Air Force and NASA provide most of the funding for university and industrial research in aeronautics, collectively subsidizing aerospace education and technology. They also perform most of the in-house government aeronautical research. During the 1990s, the AFRL expenditures in this area were roughly the same as NASA's (see Figures 2-5 and 2-8).

The past two decades of NASA funding for aeronautics are shown in Figure 2-5. These amounts do not include the salaries of NASA employees or the NASA facility costs (in contrast, AFRL employee salaries are included in its 6.2 budget; see Figure 2-10). These monies mostly go to fund industrial and university research (with the rest spent on in-house NASA contract personnel services and research expenses). In the past 5 years, NASA has reduced its support for aeronautics by over 40 percent (NASA Office of Aerospace Technology, 2003).

While not all of NASA's research and technology investments are directly relevant to Air Force systems, many are. At the more basic levels (corresponding to DoD 6.1 and 6.2 categories), technologies such as materials, propulsion, and electronic devices are often applicable across a wide range of applications, both military and civil. Even at the more applied levels (DoD 6.3), many technologies are relevant to both civil and military applications.

In summary, from FY 1988 to FY 1998, the Air Force S&T investment fell significantly—approximately 45 percent in real terms. It then rose from 1998 to 2003, mainly due to Congress's yearly increasing of S&T funding over the amount requested by the President. By FY 2003, Air Force S&T funding had recovered about half the early 1990s decline. Part of the FY 2003 increase, however, was due to DoD's moving programs into the Air Force S&T funding line that previously had not been considered to be S&T. In the FY 2004 PBR, DoD again moved programs under the Air Force S&T top line that previously had not been there. Taking these programs into account, the FY 2004 funding requested for the continuing Air Force S&T program was less than that received for FY 2003. Plans for similar reductions appear to be in place for FY 2005. Currently, the Air Force relies on funding from non-Air Force S&T sources to supply approximately 40 percent of the AFRL budget. The Air Force also benefits from the research and technology development conducted by other agencies, principally NASA.

Need for Increased S&T Investment

Ensuring that the Air Force has appropriate and sufficient technology to counter future threats is now more difficult than at any time in the past, in part because both the challenges posed by the threats and the opportunities offered by technologies are more numerous and more complex as a result of the inexorable advances of scientific discovery and engineering applications. The words "higher, farther, faster" are given new meaning by the evolving military applications of directed energy and information warfare—to name just two areas. As a result, for example,

> Potentially hostile nations that cannot afford a large military force can afford today's advanced information systems, as can terrorist

> groups. With these technologies, access to the world through global connectivity, and hostile intent, such adversaries can cause great harm at low cost. (NRC, 2001a, p. 4)

New systems such as directed energy and information warfare represent the fruits of past S&T investments. As they pass through full-scale development and into deployment, experience suggests that new technology needs will rapidly be identified. Thus, S&T in such areas is really just at the end of the initial phase; much more will be needed to support and evolve fielded systems and their descendants.

In addition, nano, biological, and the ever-expanding information sciences are certain to offer new opportunities to improve security, add to the technological edge, and save lives—as an example, see the recent NRC report *Implications of Emerging Micro- and Nanotechnologies* (NRC, 2002).

At times, new challenges and opportunities such as those just discussed can be funded by disinvesting in ongoing areas that can be transitioned or that are no longer productive toward needed Air Force capabilities (zero-based transfers). That does not mean, however, that satisfying the need to invest in such new opportunities as nano, biological, and information sciences should always be at the expense of ongoing programs. Also, NASA has significantly reduced its support for aeronautics, but Air Force needs for many of these technologies for advanced air vehicles and access to space have certainly not slackened. Further, decisions on 6.1 research support to universities, for example, can have far-reaching impact, even to the point of affecting curricula; once made, such decisions cannot be readily or quickly reversed. There are likely to be times, therefore, when increases in basic and applied research will be appropriate in order to protect the future. Considering the increased tempo of operations and demands for modernization to meet the evolving threats, the present is one of those times.

In summary, the committee believes that there are many indicators suggesting that increased Air Force S&T investment may be appropriate. These include numerous new and complex threats, new opportunities opened up by basic research, new classes of systems entering the Air Force inventory, ongoing S&T programs for which the investments need to maintained, and reductions in non-Air Force S&T efforts from which the Air Force benefits.

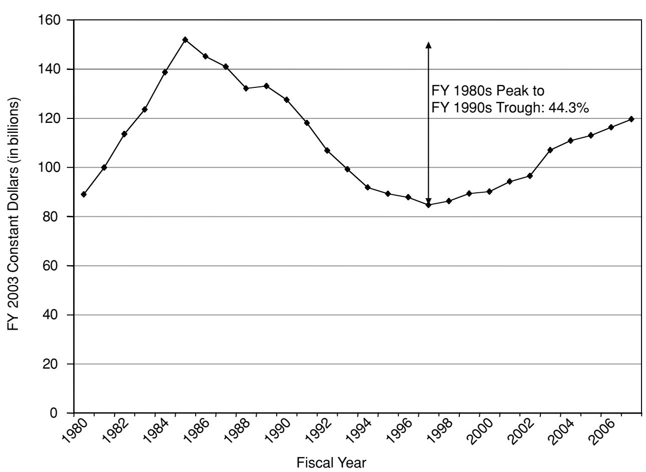


FIGURE 2-6 Air Force TOA (TOA through FY 2002, PBR for FY 2003, FYDP for FY 2004–FY 2007). SOURCE: DoD, 2002a.

Balancing the S&T Top Line with Other Requirements

With constrained budgetary resources, all possible combinations of readiness, modernization, and S&T investment entail risk. Increasing investment in one area may reduce risk in that area but increase risk in other areas. The trade-offs that must be made are greatly complicated by uncertainty in the size of risks accompanying particular investment levels and uncertainty in comparing risks among areas. A number of the studies summarized in Appendix E have addressed this challenge. The Defense Science Board (DSB), for example, has recommended increasing the level of DoD S&T funding to a fixed percentage of the total DoD TOA (DSB, 2000, 2002). In declining to endorse the DSB's percentage of TOA recommendation, the Air Force Scientific Advisory Board (SAB) noted that such an approach restricts leadership's ability to manage the total budget in times of extreme constraints—that is, to balance, and hopefully minimize, risk. Instead, the SAB recommended that the Air Force tie its S&T investment strategy to its long-range plan and vision (SAB, 2001).

As background for understanding the Air Force S&T funding allocation relative to the competing demands, the committee noted that during most of the 1990s the Air Force was faced with the demands of a high operational tempo, including Northern and Southern Watch over Iraq, operations in the Balkans, and numerous humanitarian actions—all in the face of funding that declined through FY 1997 and remained relatively low through the decade (see Figure 2-6).

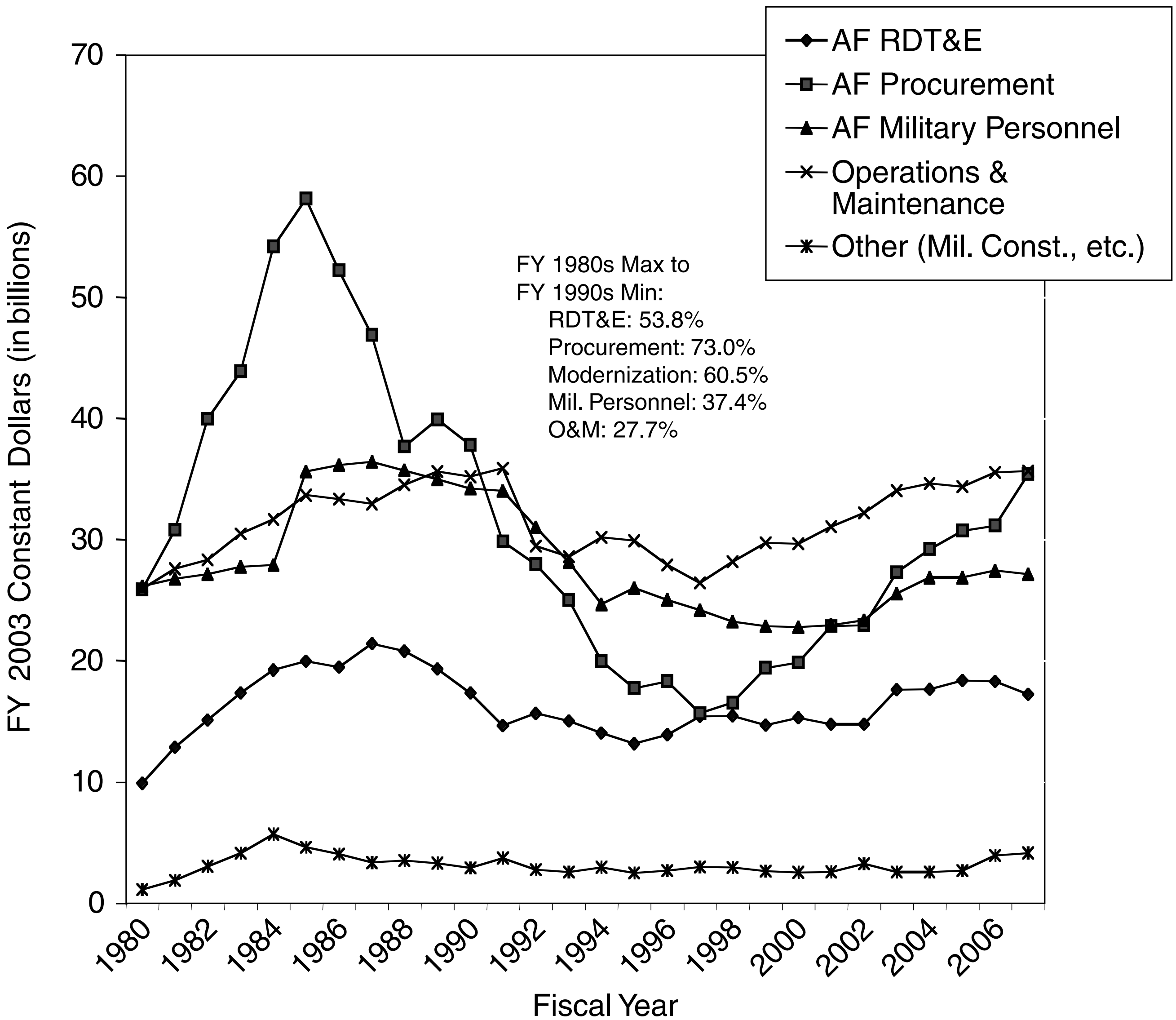


FIGURE 2-7 Air Force TOA by category (TOA for FY 1989–FY 2002, PBR for FY 2003, FYDP for FY 2004–FY 2007). SOURCE: DoD, 2002a.

Comparing Figures 2-1 and 2-6, the committee noted that overall Air Force S&T funding fell from its peak in the 1980s by about the same percentage as the decline in overall Air Force TOA. While the S&T funding in Figure 2-1 has in fact kept pace with recent increases in the overall Air Force TOA, this would not have been the case had the Air Force plan been implemented (reflected in Figure 2-2 by the curve for the PBR less the OSD additions).

The Air Force distributed the overall TOA illustrated in Figure 2-6 among the major appropriation categories, as shown in Figure 2-7. The figure shows that by the mid-1990s, modernization (RDT&E [research, development, test, and evaluation] plus procurement) was reduced by about 60 percent and personnel by about 35 percent, reflecting the decline in overall Air Force funding. Although these reductions were partly offset by force reductions and reduced near-term emphasis on strategic nuclear capabilities, the result has been aging avionics (NRC, 2001c), aging platforms, and aging infrastructure (NRC, 2001b), as well as personnel problems (NRC, 2001a). As the total funding shown in Fig-

TABLE 2-1 Funding Increases in Real Terms (constant year dollars)

Title	Percentage Increase from FY99 TOA to FY03 PBR	Percentage Increase from FY02 TOA to FY03 PBR
TOA	19.9	10.9
Personnel	11.8	9.5
O&M	14.6	5.7
Procurement	40.7	19.0
RDT&E	19.9	19.2
S&T[a]	25.0	4.4

[a]Without the OSD additions discussed earlier, S&T would have grown only 3 percent from the FY 1999 TOA to the FY 2003 PBR and would have declined by 14 percent from the FY 2002 TOA to the FY 2003 PBR. The growth from the FY 1999 TOA to the FY 2003 appropriation was 36.1 percent, and from the FY 2002 TOA, 13.6 percent. SOURCE: DoD, 2002a.

ure 2-6 started to increase so that at least some of the demands could be addressed, the war on terrorism and the desire for force transformation created new demands. As a result, the Air Force leadership, which must balance the competing funding demands (subject to OSD and OMB oversight), had to make hard choices. Table 2-1 reflects these decisions as the change in the major budget categories from FY 1999 (planned about the time the concerns referred to in Chapter 1 started to arise) to FY 2003 (the latest data to which the committee had full insight into the Air Force's plans).

As shown in the table, the largest increase since FY 1999 has been in procurement, where (as shown in Table 2-2) the increase is primarily to address aging platforms, special projects and programs, infrastructure, and munitions, including those used heavily in Afghanistan.

The data in Table 2-2 also show that the second-largest percentage increase since FY 1999 has been in S&T, largely due to congressional action, as discussed earlier. Conversely, from FY 2002 TOA to the FY 2003 PBR, after the Air Force balanced its program, the increase in S&T was only 4.4 percent (see Table 2-1). (As noted earlier, without additions made by OSD for Transformational Wideband MILSATCOM and for Special Programs, the PBR for S&T for FY 2003 would have been below the S&T TOA for FY 2002.)

The data in the last column of Table 2-1 show that most of the increases in personnel funding and RDT&E funding over the 4-year period occurred in the FY 2003 PBR. The increase in personnel funding presumably reflects pent-up demand for pay and benefits. The breakout for RDT&E is shown in Table 2-3.

As shown in Table 2-3, the increases in RDT&E funds primarily address aging platforms and avionics: The Joint Strike Fighter (intended to replace the F-16 and A-10) accounts for nearly one-third of the increase,[8] while the F-22 (the replacement for the F-15) and the C-130J all address aging platforms. The C-5 and C-130 programs address life-extension activities. Among the space satellite systems, Advanced EHF is an upgrade and replenishment for MILSTAR, NPOESS for the Defense Meteorological Satellite Program (DMSP), GPS III for GPS II, and SBIRS High for the Defense Support Program (DSP).

The next several paragraphs examine the methodology used by the Air Force to guide the decisions summarized in Figure 2-7 and Tables 2-1 through 2-3. To balance its budgetary requirements and set the S&T top line, the Air Force works within DoD's Planning, Programming, and Budgeting System (PPBS). The PPBS is applied to develop the overall program for the Air Force, the other services, and the so-called Defense-wide programs managed directly by the defense agencies and OSD. The Air Force budget consists of recommended funding for operations and maintenance (O&M); personnel; procurement; research, development, test, and evaluation (which includes S&T); and other areas to be proposed by DoD to OMB and subsequently to the Congress in the President's budget.

Under the PPBS, AFRL recommends the allocation of the top line S&T funding among 6.1, 6.2, and 6.3 research categories and then to specific programs. Based on AFRL's input, the Defense Planning Guidance (DPG), and other considerations, the Air Force determines the budget allocation for S&T. This is an iterative process.

In some years, AFRL submits recommendations for increased funding in the form of unfunded requirements. The committee understands that in recent years, requirements above the guidance budget level either have not been submitted by AFRL or have seldom been

[8]The Joint Strike Fighter EMD increase was 32 percent of the total RDT&E increase, but that amount was partly offset by reductions in the budget for EMD of other programs so that the overall EMD increase is only 23 percent.

TABLE 2-2 Allocation of Procurement Increases from FY 1999 to FY 2003

Procurement Appropriation	Percentage Increase: FY99 TOA to FY03 PBR	Primary Sources of Increase
Aircraft (3010)	42	F-22, C-17, V-22 (partially offset by reductions for older platforms)
Other (3080)	34	Special support projects, electronics and telecommunications equipment (base communications, tactical C-E, base information), and vehicular equipment (material handling equipment)
Missile (3020) (includes space)	16	Special Programs, Minuteman modifications, replenishment/ upgraded satellites, air-launched missiles
Ammunition (3011)	8	Rockets, bombs (including JDAM, WCMD), flares, fuses

SOURCES: U.S. Air Force Committee Staff Procurement Backup Book, FY 2001 Amended Budget Request, February 2000; U.S. Air Force Committee Staff Procurement Backup Book, FY 2003 Budget Estimates, February 2002.

elevated to the leadership, given their slim chances of being funded.

The Air Force then balances the risks for readiness (O&M and personnel), modernization (development, test, and evaluation; and procurement), and military construction against those of S&T in preparing funding allocations in its program objectives memorandum (POM). Thus, in assessing whether "appropriate and sufficient technology is available to ensure the military superiority of the United States and counter future high-risk threats," as defined in the statement of task for the committee, the Air Force leadership has to balance the risks to near-term military superiority by balancing the risks among the elements of its longer-term programs.

AFRL submits its S&T funding proposals about 2 years before funding becomes available, and planning must precede submission. Action within the PPBS is subsequently completed about 1 year before the S&T details are set in the annual appropriations act. Once the funding is available, S&T tasks must be executed to provide the technology basis for the acquisition programs, usually a multiyear step. Thus, planning the S&T program must include long-range forecasts of factors such as technology needs and scheduling for the acquisition programs that may apply the resulting technology.

The preceding discussion was necessarily abbreviated; however, the point is that, in a fiscally constrained environment, achieving the best balance between Air Force S&T and other demands within a specific top line budget is a complex problem. The Air Force procedures to generate an appropriate S&T top line by building from the bottom up (i.e., assembling specific

TABLE 2-3 Allocation of RDT&E Increases from FY 2002 to FY 2003

RDT&E Budget Activity	Percentage Increase: FY02 TOA to FY03 PBR	Primary Sources of Increase (Rank Ordered)
S&T	3	Advanced technology development
Demonstration and validation	16	Advanced EHF, Transformational Wideband MILSATCOM, NPOESS, GPS III
EMD	23	Joint Strike Fighter, SBIRS High, ICBM, Counterspace Systems
RDT&E management support	–1	
Operational systems development	58	F-22, GPS, AWACS, C-5, C-130, selected activities, C-130J, MILSATCOM terminals

SOURCE: DoD, 2002b.

technical tasks) are just as complex and involve the work of many people over multiple years.

In summary, the Air Force leadership must set the top line funding for S&T in competition with other elements such as readiness and modernization (other than S&T) within fiscal constraints established by the President and the Secretary of Defense. It is a difficult, complex task to which OSD and the Air Force apply a complex, multiyear, resource-intensive process. The committee was not presented with convincing arguments that the resulting S&T funding is now significantly out of balance with its budget competitors.

IMPORTANCE OF S&T FUNDING STABILITY

Perhaps the dominant characteristic of the S&T funding shown in Figure 2-1 is instability. Yet, the committee judges that stable funding is required for the effective and efficient generation and maturation of new technology over the long term, from 6.1 research, through 6.2 programs, 6.3 critical experiments, and finally 6.3 advanced technology demonstrations (ATDs) into technology ready for application when needed in an acquisition program. This stability is needed both for the funding plans of individual projects and for the longer-term health of the research organizations in which they reside.

Unplanned funding decreases interrupt or stretch out work, prevent or delay transition, and may lead to the closing of valuable facilities or the dissolution of research and development teams. Attempts to maintain teams may spread funding too thin across too many programs. To the extent that such "keep-alive" funding is applied, the result is typically little progress. Decreases not planned well in advance also result in the inefficiencies of "broken" programs. Cumulative decreases over many years, as was the case in the reduction of over 45 percent from FY 1989 to FY 1998 shown in Figure 2-1, could have a proportionally larger effect on program execution through continuing management distraction, associated workforce reductions, and declining morale.

Increases can also have destabilizing effects. Increases that occur too fast can be greater than the system can efficiently absorb. It takes time to put into place S&T projects that are well planned and structured, strongly integrated with related projects, and that are relevant and contribute to overall S&T objectives. Furthermore, funding controlled by sources external to the Air Force can be cut off without concurrence or consultation, contributing substantial instability.

The committee recognizes that, as with any DoD or government funding line, stability is a difficult target, given exogenous factors such as congressional mandates, abrupt DoD transfers of large programs into and out of the S&T budget, and unplanned operations. Nevertheless, the committee judges that stability, both in fact and in prospect, is a key characteristic of successful S&T programs and should be adopted as a planning guideline by the Air Force.

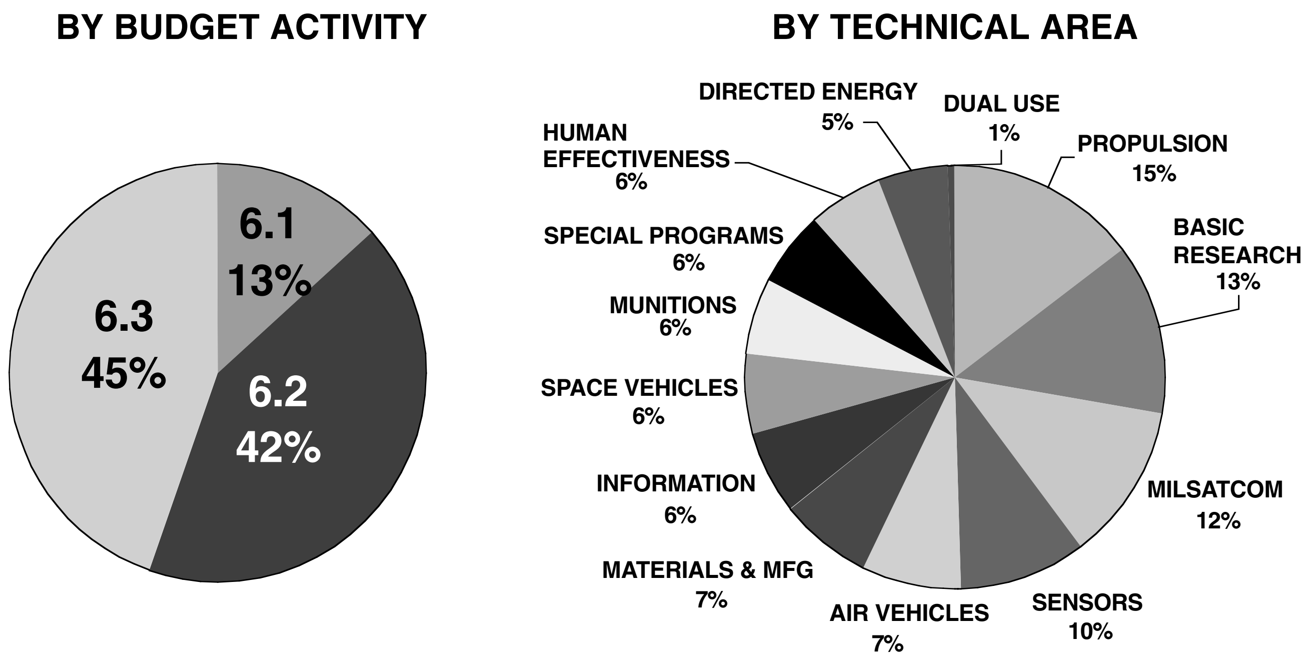
AIR FORCE S&T PROGRAM INTERNAL BALANCE

The Air Force reports that it regards the issue of investment balance as having multiple aspects: topical areas (e.g., air versus space), expected payback time (near- versus mid- versus long-term), and the S&T total versus other uses for the funds. It further reports that it has addressed balance by taking action on 4 of some 14 recommendations embodied in the reports referenced in Chapter 1. The discussion here will focus on the balance among near-, mid-, and long-term efforts, consistent with the committee's statement of task.

As indicated at the beginning of this chapter, the Air Force S&T program consists of three distinct budget activities: basic research (for brevity, often denoted as 6.1), applied research (6.2), and advanced technology development (6.3).[9] The discussion that follows identifies 6.1 as long-term, 6.2 as mid-term, and 6.3 as near-term.

The Air Force S&T program proposed for FY 2003 consists of 27 program elements (PEs): 1 covering all of 6.1, 11 for 6.2, and 15 for 6.3. The funds in the 6.1 PE are divided among 11 science and engineering areas. These, in turn, consist of a large number of individual projects and tasks. For example, in FY 2001, there were 132 AFRL 6.1 projects and 337 grants and contracts to universities and industry (Carlson, 2002). The funds in the 11 PEs for 6.2 are spread over 45 projects, while the 15 PEs for 6.3 are divided among 44 projects. Overall, the committee understands that subsumed within this arrangement are a thousand or more individual tasks. The volume of data needed to describe

[9]The RDT&E Budget Activities, including those for S&T, are defined in the DoD Financial Management Regulation, Volume 2B, Chapter 5, Section 050201, June 2002.



BAC	FY03 PBR (in millions)
6.1	219.1
6.2	697.5
6.3	742.9
TOTAL	**1,659.6**

FY03 BUDGET:
$1.660 Billion

TECHNICAL AREA	FY03 PBR
PROPULSION	243.5
BASIC RESEARCH	219.1
MILSATCOM	195.0
SENSORS	162.7
AIR VEHICLES	123.0
MATERIALS & MFG	121.9
INFORMATION	105.2
SPACE VEHICLES	100.9
MUNITIONS	98.3
SPECIAL PROGRAMS	97.3
HUMAN EFFECTIVENESS	96.2
DIRECTED ENERGY	85.8
DUAL USE	10.6
TOTAL	**1,659.6**

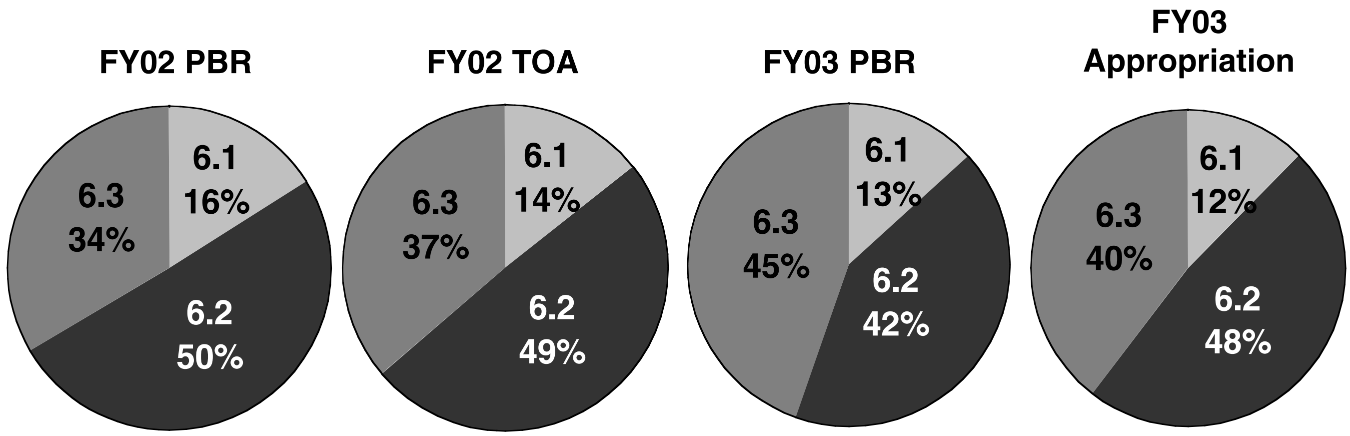
Numbers may not add due to rounding.

FIGURE 2-8 Proposed Air Force S&T FY 2003 budget. SOURCE: Ruck, 2002.

each task's technical and funding plan constrains the depth of any review that is practical outside AFRL. Any practical approach for allocating S&T funding must account for this reality.

The Air Force S&T funding for 6.1, 6.2, and 6.3 proposed by the President for FY 2003 is shown in Figure 2-8. The split of 6.2 and 6.3 funding into technical areas is also shown. The data show that among the 6.2 and 6.3 categories, propulsion receives the most funding ($243.5 million), followed by MILSATCOM ($195 million—one of the OSD additions), sensors ($162.7 million), air vehicles ($123 million), and materials and manufacturing ($121.9 million). These top five categories make up over 50 percent of the total budget.

The trend in funding from FY 2002 to FY 2003 in 6.1, 6.2, and 6.3 is shown in the Figure 2-9. The FY 2003 PBR for 6.1 and 6.2 decreased relative to both the



BUDGET ACTIVITY	FY02 PBR	FY02 TOA	FY03 PBR	FY03 Appropriation
6.1	224.2	229.7	219.1	224.0
6.2	706.6	779.6	697.5	865.0
6.3	471.7	580.7	742.9	718.0
TOTAL	1,402.5	1,590.1	1,659.6	1,807.0

Numbers may not add due to rounding.

FIGURE 2-9 Air Force S&T by budget activity (FY 2003 constant dollars, in millions). SOURCES: Hunsberger, 2002; DoD, 2002a; Jones, 2002.

FY 2002 PBR and TOA; 6.3 would have decreased without the OSD additions discussed earlier. For FY 2003, the 6.1 appropriation was higher than the PBR but less than the FY 2002 TOA. The 6.2 FY 2003 appropriation increased significantly. The 6.3 FY 2003 appropriation also provided a significant increase over the FY 2002 TOA but was lower than the PBR because of the issues regarding the OSD additions.

Basic Research (6.1)

The 6.1 activities are defined in the DoD Financial Management Regulation (FMR).[10] The Air Force associates 6.1 with Technology Readiness Levels (TRL) 1 and 2.[11] Key phrases in these definitions are "directed toward greater knowledge or understanding of the fundamental aspects of phenomena . . . without specific applications . . . fundamental knowledge and understanding . . . related to long-term national security needs . . . farsighted . . . involve pre-Milestone A efforts" and "Invention begins. . . . The application is speculative." Thus, the 6.1 budget managed by the Air Force Office of Scientific Research (the basic research arm of AFRL) is primarily one of "technology push," not necessarily directed toward a specific military application. In addition, the committee notes that a significant portion of 6.1 funding goes to the nation's universities and colleges, so it has the very important additional benefit of helping to build the pool of scientists and engineers (S&Es)—an important consideration, since the Air Force continues to face a shortage of S&E personnel (see Chapter 3). The principal output of 6.1 activity is knowledge in the form of papers published in the open literature. Most of the technological underpinnings of today's military capabilities started at this fundamental level. Thus, 6.1 funding contributes to both national

[10]DoD FMR, Vol. 2B, Section 050201. Generally consistent but less detailed definitions are also contained in DoDI 5000.2 on the operation of the DoD acquisition system.

[11]See GAO/NSIAD-99-162, p. 68, for definitions of the TRLs (GAO, 1999).

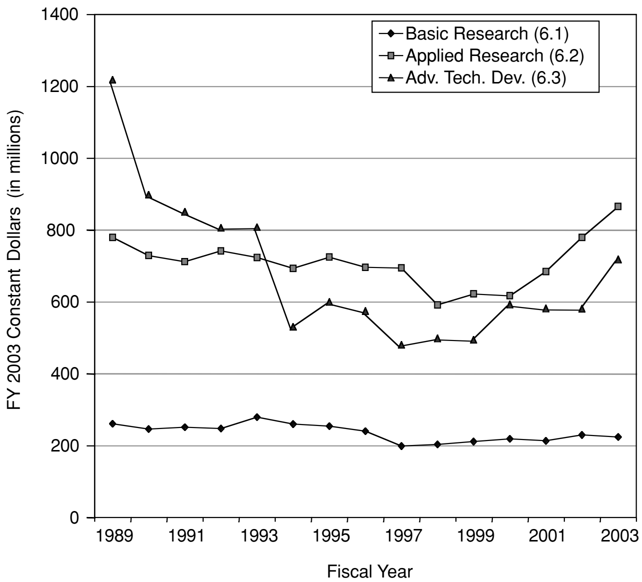


FIGURE 2-10 Air Force S&T funding trends by budget activity (TOA through FY 2002, appropriation for FY 2003). SOURCES: Hunsberger, 2002; DoD, 2002a.

security and economic security. The 6.1 funding over time is shown in Figure 2-10.

As shown in Figure 2-10, 6.1 funding declined during the mid-1990s but partially recovered over the late 1990s and early 2000s. Work under 6.1 sets the stage for future technological opportunities, usually a decade or more in the future. These investments—characterized by uncertain outcomes, high risk, but possible high reward (for example, support for the work that led to the invention of the laser, adaptive optics, the development of self-healing polymer composites, dip pen nanolithography for nanoelectronics, and improved tracking algorithms)—are intended to open new technological opportunities and to prevent technological surprise. Because the outcome is uncertain and not usually related to near-term operational needs, the 6.1 program is perhaps the easiest budget line to cut arbitrarily, even though doing so mortgages the future from the viewpoint of both technology and personnel. The committee suggests that making the flow of technology from 6.1 through 6.2/6.3, development, and into the field more readily apparent to the major operational commands and Air Force corporate leadership through the use of current and planned as well as retrospective examples would increase the insight into and interest in basic science on the part of Air Force senior leadership.

Applied Research (6.2)

The DoD FMR cited above also defines 6.2, which the Air Force associates with TRL 3 and 4. Key phrases from these definitions are "study to understand the means to meet a recognized and specific national security requirement . . . translates promising basic research into solutions for broadly defined military needs . . . non-system specific technology efforts . . . directed toward general military needs with a view toward developing and evaluating the feasibility and practicality of proposed solutions . . . precedes system specific research . . . pre-Milestone B efforts, also known as Concept and Technology Development phase tasks, such as concept exploration efforts" and "proof of concept . . . physically validate analytical predictions of separate elements of the technology. . . . Component and/or breadboard validation in laboratory environment . . . establish that the pieces will work together."

In addition to the current Air Force administrative structure, 6.2 also funds most of the AFRL manpower and infrastructure.

Figure 2-10 also shows the historical funding trends for 6.2. Like 6.1, 6.2 funding also declined in the mid-1990s but has recovered and now exceeds the level of FY 1989.

Advanced Technology Development (6.3)

Key phrases from the definitions in the DoD FMR and TRL 5 and 6 for 6.3 include "development of subsystems and components and efforts to integrate subsystems and components into system prototypes for field experiments and/or tests in a simulated environment . . . includes concept and technology demonstrations of components and subsystems or system models . . . The models may be form, fit and function prototypes or scaled models . . . proof of technological feasibility and assessment of subsystem and component operability and producibility rather than the development of hardware for service use . . . direct relevance to identified military needs . . . pre-Milestone B efforts, such as system concept demonstration, joint and Service-specific experiments or Technology Demonstrations . . . do not necessarily lead to subsequent development or procurement phases" and "Component and/or breadboard validation in relevant environment . . . System/subsystem model or prototype demonstration in a relevant environment . . . in a high fidelity laboratory environment or in simulated operational environment."

The 6.3 activities are divided into two major categories—critical experiments and advanced technology demonstrations. Critical experiments address technology development efforts that were enabled by 6.2 initiatives and which may subsequently advance to ATDs. ATDs represent the final or most advanced phase of S&T development just prior to transition to an acquisition program for development, production, and deployment to an operational user.[12] The committee was informed that AFRL intends to divide 6.3 funding about evenly between critical experiments and ATDs.

As also shown in Figure 2-10, 6.3 funding declined sharply in the early 1990s, from about $1.2 billion in FY 1989 to about $530 million in FY 1994 (in constant FY 2003 dollars). It then ranged between about $480 million and $600 million, rising to $718 million in the FY 2003 appropriation.

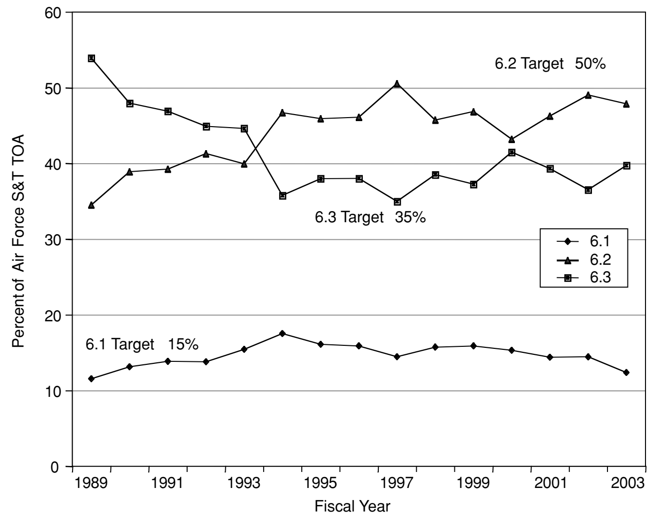


FIGURE 2-11 Percentage split of Air Force S&T TOA between 6.1, 6.2, and 6.3. SOURCES: Hunsberger, 2002; Jones, 2002.

ATDs and Transition to 6.4 and Following Budget Activities

Recent Air Force management initiatives have focused ATDs on projects expected to be ready to transition to 6.4 or other acquisition budget activity after one more development cycle. Key phrases from the DoD FMR for the activities under 6.4, Advanced Component Development and Prototypes include these: "involve efforts prior to Milestone B . . . include technology demonstrations . . . Completion of Technology Readiness Levels 6 and 7. . . . A logical progression of program phases and development and/or production funding must be evident in the FYDP."

The Air Force plan is to restrict ATDs to projects for which a major Air Force Command has programmed or plans to program funding for transition. This is an attempt to jump technology across the traditional gap between S&T and acquisition programs and ultimately into fielded capability. The Applied Technology Councils (ATCs), a relatively new Air Force management initiative, provide forums to ensure warfighter interest and commitment to transition for each ATD (see the discussion of ATCs in Chapter 3).

Figure 2-10 portrays the historical balance between the TOA for 6.1, 6.2, and 6.3 in constant year FY 2003 dollars. Figure 2-11 shows the same data as a percentage of the total annual S&T TOA.

Figure 2-11 also shows the Air Force targets for a balanced S&T portfolio: 15 percent for 6.1, 50 percent for 6.2, and 35 percent for 6.3 (Brandt, 2002). The allocations have been near the targets since the mid-1990s, essentially "on target" in FY 2002, and would have been near the targets in FY 2003 without the OSD additions discussed earlier (6.1 and 6.2 slightly above and 6.3 slightly below). As a matter of completeness, the committee notes that, like the constant year dollar level, the allocation to 6.3 is low compared with that in FY 1989 and the early 1990s.

Comparing Balance Among the Services

The 6.1, 6.2, and 6.3 funding balance among the services is compared in Table 2-4. As shown in the table, all three services have, on the average over FY 1989 to FY 2003, allocated the least to 6.1 and slightly more to 6.2 than to 6.3. The primary difference among the services is that the Navy allocates twice the fraction to 6.1 (and correspondingly less to 6.2 and 6.3) compared with the other services.

SETTING THE PROPER S&T INVESTMENT LEVEL

The committee was led by the totality of the factors discussed in this chapter to conclude that the most im-

[12] In some cases, ATDs may provide a residual capability that can be used operationally, but they are not usually designed with the supportability features required for sustained operational use.

TABLE 2-4 Percentage of Service S&T TOA, Average over FY 1989 to FY 2003

Service	6.1	6.2[a]	6.3
Army	12.9	43.8	43.2
Navy	27.3	38.6	34.0
Air Force	14.5	43.6	41.9

NOTE: Some rows may not total to 100 percent because of rounding.
SOURCES: Hunsberger, 2002; Jones, 2002.
[a]Air Force includes laboratory personnel salaries in 6.2; Army and Navy do not.

portant objective is to achieve basic stability in Air Force S&T. It also believes that S&T funding should be increased with modest, realistically achievable real growth to a sustainable funding level. The committee judges such a guideline to be critical in light of the deleterious effects of instability and the need for increased funding discussed earlier. It is clear that there are very real major opportunities and needs for new S&T investment. Since there was not time for a review of the content of the Air Force S&T portfolio, the committee cannot judge from first-hand information how much of this demand can be met by the curtailment of current programs. The committee notes, however, that for the past 5 years, the Air Force Scientific Advisory Board has scrubbed the content of the program in great detail and presumes that the board has done a thorough and competent job; thus, much of the new emphasis must come from new investment.

The question of how much the Air Force should invest in S&T is ill posed, so elaboration is required. The question implied in the committee's statement of task is Is the Air Force S&T program (and by implication its budget) sufficient to counter future high-priority threats and ensure military superiority? This is a different question from that addressed each year by the Air Force leadership (and its DoD and congressional oversight), which is What should the Air Force S&T budget be in that year given competing budget priorities? The reports referenced in this committee's statement of task use still other criteria. The SAB recommended that the Air Force S&T investment be determined on the basis of the cost of the S&T program needed to satisfy the Air Force's critical future capabilities (SAB, 2001). The SAB did not specify an investment level, but implied that the current level was too low. The Air Force Section 252 review (discussed in Chapter 3) concluded that the investment needed to satisfy fully the Air Force's short-term objectives and long-term challenges was roughly twice the investment then planned. The DSB and Quadrennial Defense Review put forth a percent-of-TOA approach, recommending, for example, that the DoD S&T investment be set at 3 percent of DoD TOA (significantly above the current level) (DSB, 2000, 2002; DoD, 2001). The AFA expressed concern about the decline in the Air Force S&T investment since the end of the Cold War and recommended that decline be reversed (AFA, 2000). A previous NRC committee (NRC, 2001a) recommended that the Air Force S&T investment be increased to 1.5 to 2 times its FY 2001 level. While these recommendations have rationales in the respective reports, most are not based on quantitative analysis.

This committee believes that stability, in fact as well as in prospect, is as important as a specific (reasonable) S&T funding level. Within the context of stability as a governing principle, what is the proper level of S&T funding and how do we get there? The committee is aware of the extreme difficulty in maintaining funding stability under the current annual budgeting process. Nevertheless, such stability is important to the future of the Air Force and the nation's security. Given a judicious choice of funding level and proper priority by Air Force leadership, the committee believes that it is possible to stabilize the S&T funding to a much greater degree than the historical record would indicate. The objective is to avoid both the lows of the 1990s (which resulted in the concerns described in Chapter 1) and the highs or peaks of previous periods (that proved to be unsustainable and were always followed by years of debilitating declines).

The first question, establishing the proper S&T funding level, is challenging. Addressing the question of whether the S&T program is sufficient to counter future high-priority threats and ensure military superiority comprehensively and in a substantive, quantitative manner would require detailed study of the threats (current and projected), the current S&T program, and future needs and opportunities. It would need to evaluate the costs of pursuing specific technologies as well as to assess the risks in not pursuing them. Most likely, it would need to be conducted at a classified level. Such an effort on a $1.5 billion program divided into some 27 program elements containing more than 200 projects was well beyond the scope of this 7-month study.

While lacking an analysis-based, quantitative assessment as discussed above, it is possible to examine the issue of the proper funding level by addressing the second question, how to get there. The committee believes that the approach of 2 percent annual real growth over the 6-year period of the Future Years Defense Program (FYDP) has merit. This increase is modest in terms of annual growth, manageable by AFRL, and, in the committee's judgment, realizable within the pressures facing the Air Force budget. This is the same growth rate that Congress, in both the FY 1999 and FY 2000 National Defense Authorization Acts, said that the Secretary of Defense should have as an objective for defense S&T funding, especially Air Force S&T funding (U.S. Congress, 2000, 2001). Over the 6-year period of the FYDP, a 2 percent real growth rate would bring the Air Force S&T budget to about the average level of the past two decades. This represents a 12 to 14 percent increase over the FY 2004 PBR (taken as a reference level). This increase would provide funding to pursue new requirements and opportunities beyond those that could be funded if existing programs were trimmed. The committee notes that this investment is still below (but closer to) those of the Army and Navy.

Recommendations for the detailed distribution of a funding increase are beyond the scope of this study. Broadly speaking, however, the committee suggests that growth should be balanced among near-, mid-, and far-term opportunities. The growth should apply to the sum of 6.1 and 6.2 budgets (with AFRL leadership determining the relative growth between the two) and to the 6.3 total. The growth in 6.1 and 6.2 funds is commingled here because the committee believes that there is more of a continuum between 6.1 and 6.2 than is generally acknowledged and that it is the responsibility of the AFRL leadership to determine the relative growth between the two. The committee notes, however, that the 6.1 budget has suffered considerable atrophy over the past decade, especially compared with that for 6.2. The 6.3 advanced technology demonstrations (ATDs) are most effective in supplying the latest technology when they are completed near the time that the technology is needed by an acquisition program. As a result, the allocation between critical experiments and ATDs should be modulated according to the demands of anticipated acquisition programs.

FINDINGS AND RECOMMENDATIONS

Finding 2-1. The committee holds firmly to the view that stability in Air Force S&T funding is the most critical element of ensuring its S&T success.

Finding 2-2. Increases in the level of investment in S&T in support of Air Force missions, at least over the near term, could be productively applied to ensure the long-term security and military superiority of the nation. Supporting factors include these:

- New and emerging threats most evident after the terrorist attacks of September 11, 2001;
- The results of the S&T planning review implemented by the Air Force in response to Section 252 of the FY 2001 National Defense Authorization Act (P.L. 106-398) (which identified significant unfunded challenges and opportunities);
- New types of systems such as directed energy now moving toward the field;
- The reduced S&T investment by others from which the Air Force historically benefits; and
- New opportunities (such as in the nano, biological, and the ever-expanding information sciences).

Finding 2-3. While the balance among 6.1, 6.2, and 6.3 is different among the three services, the committee was not presented with arguments suggesting that the distribution in the balance for the Air Force should be dramatically changed.

Finding 2-4. The Air Force has not adequately addressed the concerns raised by Congress and others regarding the Air Force S&T investment level. The Air Force S&T investment rose during the late 1990s and early 2000s, primarily as a result of congressional increases. For FY 2004, however, after taking into account the movement of programs under the Air Force S&T top line that previously had not been there, the Air Force requested less funding for the continuing Air Force S&T program than was received for FY 2003. Plans for similar reductions appear to be in place for FY 2005. The committee believes that the Air Force S&T investment objective stated by Congress in both the FY 1999 and FY 2000 National Defense Authorization Acts (2 percent real growth per year over the period covered by the Future Years Defense Program) has merit. In the committee's judgment, this is modest in terms of real growth, manageable by the Air Force Research Laboratory, and realizable within the pressures facing the Air Force budget.

Recommendation 2-1. The committee recommends that the Air Force S&T budget be grown, in accordance with the investment objective stated by Congress. When that level is achieved, every effort should be made to keep it there, thereby assuring future S&T investment stability.

Finding 2-5. The Air Force S&T budget covers about 60 percent of the funding for the Air Force Research Laboratory (AFRL). For the remainder, AFRL leverages funding by other Air Force programs, Defense-wide S&T programs (principally the Defense Advanced Research Projects Agency), and other government sources. The benefits of such leveraging are constrained by the direction that comes to AFRL with the external funding and by dependence on the paths taken by the external entities but magnified by the range of innovation and risk taking that consequently drive Air Force modernization. The committee is concerned that additional increases in non-Air Force S&T funding could further jeopardize stability and result in the Air Force's losing the ability to mature the S&T needed by the acquisition programs.

Recommendation 2-2. The balance between Air Force S&T and other sources of AFRL funding should be monitored with regard to impact on the stability of the total S&T program and the maturation and transition of the technology needed for acquisition programs.

3

Workforce, Planning, and Advocacy and Visibility

INTRODUCTION

The issues discussed in this chapter are organized in three broad sections that collectively address three items in the synthesis of concerns and recommendations presented in Chapter 1 (see Table 1-1). The first section is "Scientific and Engineering Workforce." The second section, entitled "Planning," includes "Compliance with Section 252 [of the FY 2001 National Defense Authorization Act]," "S&T Planning Options," and "Development (Capability) Planning." The third section, "Advocacy and Visibility," includes "S&T Summits," "Applied Technology Councils," and "Air Force Organizational Structure and S&T Advocate."

SCIENTIFIC AND ENGINEERING WORKFORCE

In addition to addressing issues relating to the S&E workforce, this section also provides part of the committee response to the general statement of task question Are changes made by the Air Force sufficient to ensure that concerns about the management of the S&T program have been adequately addressed?

The July 1999 Air Force chief scientist report *Science and Technology Workforce for the 21st Century* eloquently presents the case for the importance of the scientific and engineering (S&E) workforce to the efficiency and success of S&T with the statement "Any S&T organization rises and falls on the quality of its people. While excellent facilities are important, it is people, either in teams or as individuals, who accomplish the mission" (U.S. Air Force, 1999, p. 16).

In short, S&T means people. The caliber of the people involved is at the foundation of any successful endeavor, but personnel of high quality are critical in the S&T arena. If the Air Force S&T program attracts and retains good people, what follows has a high likelihood of also being good—a deep understanding of warfighter needs, a robust and logical investment strategy that addresses those needs, strong research on the right topics, sound program management (including both in-house research and extramural research performed by universities, industry, and other external entities—and the important relationship between these two modes), and expeditious transition of technology to the customer. The quality, enthusiasm, dedication, and mission-success orientation of people involved in S&T programs will make or break these programs. The workforce's connections to the national and international technical community will bring efficiency and synergism and will result in an effective military S&T program. The converse is also true: An overworked, demoralized, poorly managed workforce will narrow its scope of interests and interactions to the detriment of the S&T program.

It is important to note at the outset that the military component of the S&E workforce is, in the view of the committee, extremely important to the overall viability of the S&T enterprise and must be given adequate attention in any review of "workforce considerations." While government civilians (i.e., civil servants) account for the vast majority of government manpower in the Air Force laboratory system, a mix of government civilian S&Es and uniformed technical officers brings distinct advantages to the total S&E workforce picture. Simply stated, the advantages of a military S&E workforce component are at least threefold:

1. Young officers entering the service bring with them fresh degrees, new perspectives, and unbridled enthusiasm that infuse "new blood" into the enterprise. Even if these officers decide to leave the Air Force after a 3- to 4-year tour, they have served an important purpose because of the innovative element that only "outsiders" can bring. The key is to replace these officers as they leave the service or go to new assignments with other newly commissioned technical officers so that the latest knowledge and the freshest thinking is a hallmark of the laboratory workforce.
2. Mid-level officers who have served elsewhere in the Air Force bring a broader perspective in areas such as acquisition, logistics, and operations to the Air Force enterprise. This broader perspective complements the specialized and often narrower technical perspective of the government civilian workforce.
3. Historically, a subset of technical officers that have had laboratory experience rise to the ranks of Air Force senior leadership (e.g., general officers) and thus provide an "S&T" perspective to the corporate decision-making process in various senior forums. Perhaps the epitome was General Lew Allen, who served in an Air Force laboratory and ultimately was selected to be the Air Force Chief of Staff. Others, such as Lieutenant General Tom Ferguson and Major Generals Jasper Welch, Don Lamberson, and Fred Dopplet served in the laboratory system as junior officers and went on to play major roles in policy, acquisition, and R&D decision making. These officers were consciously nurtured, mentored, and promoted in an Air Force culture that recognized the value and contributions of talented young military scientists and engineers.

In short, an appropriate mix of military and government civilian S&Es, properly led and motivated, has proven its merit throughout the history of the Air Force.

Concerns have been expressed over the years regarding the deterioration of the nation's S&E workforce (civilian and military). This is a national problem. Enrollment in science and engineering programs at universities is down for students who are U.S. citizens (and are thus employable in AFRL), and promising foreign students are returning home as well. At present, service laboratories cannot make on-the-spot job offers to, for instance, college students who are in a position of choosing from among multiple job offers in a competitive market. The pay is usually highly uncompetitive, and compared with those of many industrial organizations, the facilities and equipment are inferior. Competition is especially keen in the areas of most need for the modern military—information, computers, and electronics. Service laboratories cannot compete for top-notch talent—people who, in many cases, are highly interested in jobs with government laboratories but are understandably unwilling to wait many weeks for approval when the private sector can provide an immediate offer of employment. Unless personnel constraints such as these are addressed immediately, the service laboratories face a downward spiral from which it will be very difficult, if not impossible, to recover.

Whatever institutional difficulties affect the Air Force's S&E workforce, these difficulties must contend with a basic supply problem. Most recently these concerns have been articulated in several DSB, SAB, NRAC, and NRC reports. The committee learned that more than 100 studies on this topic have been conducted over the past 30 years with remarkably consistent recommendations, few of which have been implemented. Here the committee focuses specifically on the concerns addressing the Air Force civilian and military S&E workforce.

Whatever long-standing problems existed within the DoD S&E workforce in the distant past have been aggravated in the past 15 years by a series of consolidations, downsizing, and hiring freezes that have prevented a renewal of the workforce. As a result, the Air Force S&E workforce, military and civilian, is well below authorizations and, in particular, is facing a near-term crisis as impending retirements further erode the civilian workforce. While the gap between authorizations and accessions may not be a very accurate measure, the size of that gap and its persistence over many years is very troubling (e.g., during 2002, the Air Force believed that it needed about 500 new entrants into the military S&E population, but it was able to add only about 320). The supply of scientists and engineers in the nation has also shrunk over the same 15-year period, and competition for the best of the supply is keen.

The analyses and tone taken in previous reports reflect a serious situation. Words such as "crisis" and "death spiral" are used to describe the current status and, more important, the future prospects of the Air

Force S&E workforce. A host of quantitative indicators support this gloom. The various reports have resulted in a plethora of recommendations, more than 30 addressing S&E workforce issues alone and directed at the Secretary of Defense, the Director Defense Research and Engineering (DDR&E), or the Secretary of the Air Force. The scope of the recommendations covers a broad range, from adjustments to the current processes governing acquisition and retention of the S&E workforce to recommendations (at the other extreme) of substantial changes in civil service or of phasing in, over time, half of the DoD R&D management and laboratory technical staff from the private sector, academia, and nonprofit organizations as attrition reduces the civil service S&E workforce.

The Air Force began, most recently, to address the S&E workforce issues during calendar year 2000, convening a special summit specifically for this purpose. The 2000 S&E Summit ("Summit I") highlighted the issues, quantified the scale of S&E shortages, and began developing a consensus on steps needed to reverse the seemingly alarming trends. Summit II, held in December 2001, resulted in plans of action addressing, in spirit, many of the prior recommendations. The personal commitment of the Air Force Secretary and Chief of Staff, as expressed in their joint memorandum (dated February 4, 2002) addressed to the S&E workforce, is encouraging (U.S. Air Force, 2001). Specific funding to initiate actions in FY 2003 has been identified, although not all of the actions have been funded. Some FY 2004 initiatives have been accelerated to FY 2003 by direction from the Air Force Secretary. Planned Air Force actions have the characteristics of incremental steps, implicitly recognizing that the overall problem is "too hard" to admit to more global solutions. Summit III, planned for December 2002 to follow up on initiatives developed earlier, was unfortunately canceled.

Without a sufficient assessment of the S&E requirements and of the skill mix needed for the future versus the supply that exists, the Air Force's decisions will not likely provide a lasting approach to addressing this important issue. The Air Force needs to conduct a credible, comprehensive review of requirements for S&E-trained people across the Air Force, including laboratories and system program offices (SPOs). This analysis needs to view the problem more broadly than just recognizing the shortfalls of today; it also must address the middle and far term (e.g., the impending retirement of large numbers of the S&E workforce might be an opportunity). If an adequate analysis of requirements can be accomplished soon, the Air Force could "hire" to the needs of the future, as opposed to simply filling the needs that are on the books. Future S&E manpower requirements are not necessarily linear extrapolations of today. Important considerations include supply, changes in weapons systems, competition from outside the Air Force for the same people, jobs requiring S&E talent that are "inherently military" and that must be filled by officers, review and revision of the Defense Acquisition Workforce Improvement Act of 1990 (DAWIA [see DoD manual DOD 5000.53-M]) to enable movement between the acquisition career fields and operational assignments, and, more generally, opportunities for promotion and assumption of additional responsibilities.

The Deputy Assistant Secretary of the Air Force for Science, Technology, and Engineering (SAF/AQR) is embarking on this journey; however, the committee urges that the process and progress be carefully reviewed to ensure that the right steps are being taken based on a sufficiently comprehensive analysis and that future actions are implemented consistently over the years and are measured on the basis of carefully derived metrics. As the recent Air Force "re-recruiting effort" for its S&E workforce pointed out, pay was not high on the list of what S&Es crave; thus, bonuses may not be the first thing that the Air Force should implement to help solve S&E retention and recruitment problems. Finally, whatever the Air Force does in this regard, it must be remembered that it is a "total force" problem. The people that the Air Force needs can be accessed and retained as active, reserve, or guard officers and as civilians.

There is one piece of existing legislation that, if implemented by DoD, would provide the Air Force and all other services with critically needed flexibility for managing the S&E workforce. Section 1114 of the FY 2001 National Defense Authorization Act (P.L. 106-398) eliminated the requirement for the Secretary of Defense to obtain approval from the director of the Office of Personnel Management to carry out personnel demonstration projects at Department of Defense laboratories. By eliminating this requirement, Section 1114 granted the Secretary of Defense the same authority granted to the director of the Office of Personnel Management by the *United States Code,* Title 5, Section 4703, "Demonstration Projects."

The authority granted by 5 U.S.C. § 4703 is far-reaching. It allows the conduct of personnel demonstration projects that are not limited by any civil service law or regulation relating to the hours of work per day or per week or to the methods of

- Establishing the qualification requirements for, recruitment for, and appointment to positions;
- Classifying positions and compensating employees;
- Assigning, reassigning, or promoting employees;
- Disciplining employees;
- Providing incentives to employees, including the provision of group or individual incentive bonuses or pay;
- Involving employees, labor organizations, and employee organizations in personnel decisions; and
- Reducing overall agency staff and grade levels.

With these restrictions lifted, the Secretary of Defense has the authority and great flexibility to address DoD S&E workforce problems by changing the way in which DoD manages its S&E personnel. Although not formally briefed by the Air Force on this legislation, this committee believes that Section 1114 of the FY 2001 National Defense Authorization Act (P.L. 106-398), if implemented by the Secretary of Defense, has the potential to ease the long-standing concerns of AFRL scientists, engineers, and managers.[1]

PLANNING

This section covers two aspects of planning the Air Force S&T program: Section 252 and follow-on options for S&T planning. It also covers development (capability) planning.

Compliance with Section 252

This subsection addresses the statement of task question Is the implementation of Section 252 of the FY 2001 National Defense Authorization Act (P.L. 106-398) effective to identify the basis for the appropriate science and technology program top line and investment portfolio?

Section 252 states that "the Secretary of the Air Force shall conduct a review of the long-term challenges and short-term objectives of the Air Force science and technology programs. The Secretary shall complete the review not later than one year after the date of enactment of this Act" (see Appendix B in this report). The remainder of Section 252 goes on to specify the requested budgetary assessments and the details requested of the long-term challenges and short-term objectives, as well as the completion of the process through review by the Comptroller General and subsequent submission to Congress.

According to the presentations to the committee at its May 2002 meeting by Col. Schneider (2002b) and Lt. Col. Brandt (2002), the requested procedures were completed in the fall of 2001. Some 300 people were involved in the review (100 military and 200 civilians)—90 from Air Force headquarters, 50 from the Air Force user community ("warfighters"), and 160 from the general S&T community.

Six long-term challenges were identified:

1. Finding and Tracking,
2. Command and Control,
3. Controlled Effects,
4. Sanctuary,
5. Rapid Air and Space Response, and
6. Effective Air and Space Persistence.

Each of the challenges was addressed by an integrated product team (IPT) that identified the desired capabilities within that challenge. A long-term roadmap and a listing of required research elements are given for each capability. These in turn are subdivided into their basic research (6.1), applied research (6.2), and advanced technology development (6.3) components. Altogether, the six long-term challenges identified 23 desired capabilities.

Eight short-term objectives were also identified:

1. Target Location, ID, and Track;
2. Command, Control, Communications, Computers, and Intelligence;
3. Precision Attack;
4. Space Control;
5. Access to Space;
6. Aircraft Survivability and Countermeasures;
7. Sustaining Aging Systems; and
8. Air Expeditionary Force Support.

[1]Section 1114 of the FY 2001 National Defense Authorization Act (P.L. 106-398) amends Section 342 of Public Law 103-337, the FY 1995 National Defense Authorization Act, by giving the Secretary of Defense the authority, without approval by the Office of Personnel Management, to conduct personnel demonstration projects in DoD laboratories.

Each of the short-term objectives was addressed by an IPT that identified warfighter prioritized enabling capabilities, identified deficiencies for each enabling capability, and developed an S&T roadmap to eliminate each deficiency. Altogether, the eight short-term objectives listed 41 enabling capabilities and 100 deficiencies, leading to 300 roadmapped projects.

The required funding for these endeavors shows a nearly linear ramp-up, from the present S&T budget level of about $1.5 billion to a level of about $3.2 billion by FY 2006 and remaining at that FY 2006 level for the foreseeable period beyond FY 2006.

These latter funds significantly exceed the funds programmed for Air Force S&T in the FY 2003 President's budget, according to the briefing presented to the committee on June 28, 2002, by William Borger, director of plans and programs for the AFRL. In other words, the review was not fiscally constrained by the resources planned for either S&T or the acquisition programs that must absorb the S&T.

In summary, definition of the long-term challenges and short-term objectives was completed on October 25, 2001. The Secretary of Defense (SECDEF) was notified of completion on October 26, 2001. The SECDEF notified the Comptroller General of the completion of the review on November 19, 2001, and the Comptroller General in turn reported to Congress that "the Air Force complied with the requirements of section 252 of the Fiscal Year 2001 National Defense Authorization Act" (GAO, 2002).

The ConOps Task Forces framework recently defined by the Air Force Chief of Staff will be used by the Air Staff for future planning and programming activities in upcoming POM formulations/submittals. If the short-term objectives framework continues to be used, it will have to be mapped by means of a cross-correlation matrix to the ConOps Task Forces framework if the Air Staff is to understand the relevance of the S&T program. Using the approved Air Force framework from the start would preclude the need for this cross-correlation step and eliminate the risk of "losing fidelity" during the cross-correlation process, while also being a much more efficient and straightforward process.

The committee judges that the Section 252 review, though fully satisfying the congressional directive, does not yet completely satisfy the overarching concern for a long-term and executable S&T plan because of several artifacts of the congressional directive and the "first-time-through" nature of the review. These include the lack of a mid-term category (that was not specified by Congress; i.e., the committee understands that the Air Force was advised to follow the congressional directive precisely); the assumption of a far-term schedule for ATDs and transition to an acquisition program (50 years hence in many cases); and the lack of fiscal constraints. In addition, the review did not consider the complete S&T portfolio, and it preceded the Air Force's ConOps Task Forces, which are now a key part of the Air Force's strategic planning methodology.

S&T Planning Options

The discussion in this subsection responds, in part, to the general statement of task question Are changes made by the Air Force sufficient to ensure that concerns about the management of the S&T program have been adequately addressed?

The Air Force reported to the committee that it has taken action on an overarching planning concern (which it views as follows: "The Air Force should have a long-term plan that provides for the future needs of the Air Force."), as well as about half of the specific concerns that were raised previously. The most comprehensive specific action taken by the Air Force in S&T planning was the response to Section 252, described above. The Air Force told the committee (Brandt, 2002) that its response established a framework for strategic investment guidance; that the results have been integrated into key Air Force planning and guidance documents, including the S&T Plan, Annual Planning and Programming Guidance, and Transformation Flight Plan; and that lessons learned have been identified for future reviews.

A candidate planning framework involves Warfighter Technology Areas (WTAs). AFRL reported that it is defining WTAs aimed at relating technology push to requirements pull (Borger, 2002; Rubertus, 2002). Part of the motivation for developing this framework was supposedly to insulate the S&T program from many Air Force planning and acquisition initiatives. The committee certainly understands that the Air Force S&T community cannot and should not either replan or reorient the S&T program quickly or frequently as the focus churns from program elements to core competencies, to critical future capabilities, to critical future goals, to short-term objectives and long-term challenges, to task forces, to concepts of operation, to transformation, and to pathfinders. But the committee noted a propensity for the use of "meatball" charts that indicate a relationship between frameworks by means of a matrix with dots or "x's" indicating some relationship. Such charts usually mask the enormous amount of work required to link programs substantively and quantitatively to strategic goals. To be useful, the WTAs must provide a much more substantive link than meatball charts. Further, alignment of all S&T with the WTAs would be dangerous if it does not allow for new or revolutionary concepts to arise either as a result of basic research or in response to the evolving vision and strategic plan.

In view of the discussion above, it would make sense for the Air Force to take advantage of the framework provided by Section 252, but to refine it. Here the committee expands on possible refinements. For example, prior to preparation of the FY 2005 POM, steps could be taken to ensure that the result is the "long-term plan that provides for the future needs of the Air Force," as captured in the Air Force's statement of the overarching concern for planning.

The number, scope, and technical content of the tasks may make it impractical for the major commands and corporate leadership to review in detail the complete Air Force S&T program. The committee judges, however, that the AFRL allocations of 6.2 and 6.3 can and should be at least reviewed at the margin. A suggested process is described in Appendix F.

In developing the long-term plan, the committee urges consideration of the following approaches:

1. Implementation of the lessons learned from the Section 252 review, including full consideration of mid-term technologies;
2. Selection of objectives and challenges that are measurable and related as explicitly as practical to the current Air Force strategic planning (consistent with the earlier SAB recommendation [SAB, 2001]);
3. Inclusion of S&T that is evolutionary, necessary to provide needed capabilities independent of risk or difficulty, and a continuation of ongoing activities excluded from the Section 252 review but necessary for a complete plan;
4. Establishment of milestones and transitions for an efficient program rather than the end date of the planning phase or any other artificial date and, where applicable, creation of a display of the milestones and transitions on roadmaps that link to Air Force strategic planning;
5. For programs, projects, and tasks that are funded, maintenance of roadmaps and the quantified contribution to the relevant objective or challenge;
6. Again, for funded activities, consideration of the bow-wave effect in subsequent updates of the long-range plan with feedback of the results to shape future POMs; and
7. To the extent practical, use of funding estimates concurred in by the Air Force Cost Analysis Agency consistent with USD/AT&L full funding guidance.

Above the committee used the term "evolutionary S&T." For a complete long-term plan, the importance of including evolutionary S&T is exemplified by the case of the intercontinental ballistic missile (ICBM). The invention of the atomic bomb was revolutionary. However, evolutionary developments of rocket propulsion, inertial guidance, and warhead design resulted in a truly revolutionary capability when combined into a system that could deliver a nuclear weapon across the world, with sufficient accuracy, in just minutes. The ICBM was a revolutionary capability made possible by a series of evolutionary technology developments.

The committee notes that the Section 252 review for long-term challenges had to meet four criteria: The challenges should involve compelling requirements of the Air Force, high-risk/high-payoff areas, and difficult but probably achievable results but should not be a direct extension of an ongoing program. For future reports to Congress, it may prove useful to continue tracking activities that satisfy these criteria. In addition, the following thoughts are offered. In closing the gap between short-term objectives and long-term challenges, either (1) add a category of mid-term challenges covering transition in 5 to 15 years or (2) extend the time frame of long-term challenges to cover 15 years and beyond to fill the gap or (3) define categories based on budget activities (e.g., the short-term category would apply to potential 6.3 activities, mid-term would apply to 6.2, and long-term to 6.1). As long as all potential S&T challenges and opportunities are fully addressed, the committee judges that the choice should be made on the basis of an assessment of cost and an attempt to stave off any unintended consequences that would have a negative effect.

Further suggestions in completing the long-term plan include the following:

1. Apply reinstituted development (capability) plan-

ning (see the subsection below) to develop system or system-of-systems concepts.
2. Request that industry and professional associations provide recommended technologies, concepts, or thrusts to be considered.
3. Apply WTAs only to the extent that they increase efficiency without compromising the rigor of the resulting plan.
4. Conduct an SAB quality review of the results.
5. In preparation for the subsequent, FY 2005 POM, make explicit, documented funding decisions on each task or project that falls within the POM window.
6. In the resulting program, assess the relative funding for 6.1 versus 6.2 versus 6.3, evolutionary versus revolutionary, technology push versus operational pull, air versus space and, among technical areas, compare the assessments with previous such measures like "sanity checks."
7. Review the resulting long-term plan and POM submission at an S&T Summit in the time frame of the AFMC submittal of the FY 2005 POM, and if the recommendation for a biennial, iterative review at the margin is implemented, take the results to the summit.
8. Maintain roadmaps and assessments to reflect funding changes, milestones accomplished or delayed, technical breakthroughs or problems, and so on.
9. Capture the new lessons learned and institutionalize the process to take place every fourth year (more frequently if changes to the plan or the national security environment dictates) through steps such as updates to the applicable Air Force policy documents and associated implementing instructions.

Development (Capability) Planning

This subsection addresses the statement of task question Is the revised development planning process effective to aid in the coordination of the needs of the Air Force warfighters with decisions on S&T investments and the establishment of priorities among different S&T programs?

Throughout the Cold War, the Air Force significantly benefited from consistent S&T investment. A key reason was that it had a balanced development team. To have this balance there must not only be advanced technology scientists and engineers but also conceptual designers as well as planners who can recognize the risks and formulate plans to reduce them to a practical level. During the Cold War, many programs (e.g., B-1, F-117, B-2, F-22, C-17) came out of development planning activities of the 1960s, 1970s, and 1980s. Early in the 1990s, Congress eliminated funding for development planning, and this decision was not challenged by the Air Force. To keep some development planning activities going, the funding had to come from current programs or product center operating funds, and both sources became scarcer as the military drawdown continued through the decade.

Today, a key ingredient in achieving a truly transformational future warfighting capability is widespread adoption of new system-of-systems methods and architectures, which cut across conventional stovepiped product and platform boundaries. Despite the critical need for such thinking today, given the explosion of information technology and the need for new network-centric system-of-systems constructs, a significant gap exists in the overall Air Force S&T process because there is no current organizational entity equipped or charged to perform the vital system-of-systems function. This function is in contrast to a previous development planning function, which was organized around each individual product center. Although very useful, that process tended to limit the breadth of the systems considered to those bounded by individual product center spheres of responsibility.

The Air Force has been without a development planning function for almost 10 years, and it has lost the organization and, most importantly, the people to do it. Congress and Air Force leadership have recognized the problem and endeavored to re-establish the function. AFMC commander General Lester Lyles made some initial funding available in 2002 and established an AFMC office focused on "capability" planning to lay a foundation for restoring the broad development planning function (Schulz, 2002). However, until the right people are recruited, assigned, and funded, the function—whether it is called development or capability planning—cannot even begin to achieve proper results.

S&T work is normally performed by individuals who are specialists in their fields and usually work at limits of the state of the art. To better channel their work and enhance the transition of technology to useful products, there is a need for a small group of concept-development personnel who have broad experience in many different technical areas and who can synthesize new system constructs.

The classic view of development planning in the Air Force can be described as the definition of broad requirements supporting eventual procurement of a component system. However, there is now a need to envision any component of the arsenal—from aircraft to small munitions, from space vehicles to ground support equipment—as part of an overall "system of systems" in which that component must be planned from its inception as part of the evolving overall system. Each component must be designed to enhance Air Force warfighting capability not only as a component, but also through its role in exploiting potential synergistic interactions of all components of the overall Air Force system.

The overarching capabilities of new technologies (e.g., widely and deeply embedded information technologies) should be not only innovatively exploited within Air Force "component systems" such as aircraft, but also used to enable novel new warfighting capabilities through integration of "systems of Air Force systems." Innovations at that level are increasingly likely to be the basis for major transformation of Air Force warfighting methods. Therefore, innovation at that level should be actively supported by appropriate new forms of development planning. An aircraft designer must have knowledge of aerodynamics, materials, structures, thermodynamics, electronics, and so forth. In the future, an even broader range of capabilities will routinely have to be considered when designing any new system and system of systems. That broader systems outlook is needed in order to innovate entirely new combinations of air, space, communications, sensing, control, and weapons systems or technology having new warfighting capabilities. To do this effectively, there must be constant interplay between the overall S&T community, the concept development people, and the mission analysts.

A development (capability) planning group would be a catalyst for bringing together the S&T and design communities, establishing long-range plans to sort out the most promising new systems concepts, and setting realistic schedules and funding needs. The resulting capability plan would communicate to users what the potential new developments might be and what the various choices among them are, and it would help dialogues with using commands to be truly two-way exchanges.

The AFMC commander strongly voiced his concern to the committee regarding the atrophied development planning activities, stated that he was committed to rectifying the situation, and articulated the critical value of this process in the evolution of future systems. Each of the product center commanders has recognized the need to reinvigorate development planning, and each has submitted budget inputs for it over the past few years. Despite a focus on bringing back robust development planning, funding for this activity has not survived the budget process. The committee judges that today there is inadequate funding to conduct even a minimal development (capability) planning activity.

Establishing a development (capability) planning organization with development teams and planning personnel is mandatory for improving the planning of future systems. The shortage of S&T personnel is a major worry today, but the shortage of qualified systems-of-systems analysts and concept designers with a strong systems engineering background to serve as development (capability) planners is actually more acute. Such individuals must have served an apprenticeship in more than one discipline or product area as well as having actual design experience. These skills are hard to obtain, whether working in industry or government. Since the Air Force's development planning function was eliminated many years ago, there is no ready pool of people from which to recruit to fill this void. Attracting these skilled people requires a funded budget line item, special job positions, and high-level leadership (e.g., a leader with experience reaching back to earlier development planning). The organization should be led by a general officer or senior executive service (SES) civilian and staffed with a cadre that includes personnel with operational and S&T experience. Such a group is necessary if there is to be an effective capability plan leading to innovative future warfighting systems that rapidly and fully exploit our expanding technology base. The Air Force should consider consultation with its traditional systems houses (such as The RAND Corporation and The MITRE Corporation) and experienced personnel in the other services in the reconstitution of this capability.

ADVOCACY AND VISIBILITY

This section covers S&T Summits, Applied Technology Councils, and the Air Force organizational structure and S&T advocate.

S&T Summits

This subsection addresses the statement of task question Do the biannual S&T Summits provide sufficient visibility into, and understanding and appreciation of, the value of the S&T program to the senior level of Air Force budget and policy decision makers?

A significant change initiated by the Air Force early in 2000 was the creation of S&T Summits, which involve the entire top Air Force leadership. The purposes of the summits are to better inform the operational and support leaders of the Air Force about future capabilities that can be expected from S&T programs and to help educate the S&T community on the specific needs and desires of the operators. The following are specific summit objectives: (1) review the S&T program; (2) review findings and recommendations from Congress, the SAB quality reviews, and the S&T portion of Defense Planning Guidance; (3) present technology planning initiatives and strategy for the Program Objectives Memorandum; and (4) identify candidates for the Unfunded Priority List.

The first summit was planned to last most of a day in April 2000; it was sponsored by General Lyles in his new capacity as AFMC commander and was organized by the S&T community. The audience included the Air Force Secretary, Air Force Chief of Staff, many four-star generals, and many staff generals and key civilians. The agenda covered the entire S&T portfolio to expose selected opportunities, people, and ideas within the S&T program to top Air Force leaders and policy makers. Attendees discussed S&T investment strategy and identified specific candidates for increased funding associated with zero percent real growth (i.e., Tanks Under Trees, Agile Laser Protection, Joint Battlespace Infosphere, and Directed Energy). There was also an action item to develop a corporate process for (1) stopping or slowing the pace of advanced technology demonstrations if no transition funds appear in two successive cycles of user POMs, and (2) obtaining senior leadership approval prior to S&T disinvestment. All together, nine action items resulted, and more summits were recommended.

The second S&T Summit was held in November 2000. It, too, was sponsored by General Lyles and had top-level attendees (e.g., the Air Force Secretary and Air Force Chief of Staff). The meeting included an overview of Defense Planning Guidance and congressional direction, a review of ATDs and the SAB quality review findings, and a look at the S&T investment strategy and additional investment opportunities. The meeting concluded with 13 action items.

Originally it was planned to have the summits twice a year, but the Air Force found it too difficult to schedule the top leadership twice a year. Consequently, the third S&T Summit, again sponsored by General Lyles, was held in October 2001. The audience included the new Air Force Secretary, the new Air Force Chief of Staff, the Vice Chief of Staff, the USAFE Commander, and 16 other general officers and key civilians. The Deputy Assistant Secretary for Science, Technology and Engineering opened the meeting, and the AFRL Commander made the wrap-up.

As a result of the attacks of September 11, the 2001 agenda was changed to include Active Denial Technology (nonlethal antipersonnel directed energy technology); Information Extraction (for asymmetric threat detection and warning); a Surface Target Ordnance package; Infrared Countermeasures for Aircraft (advanced ideas); and a new Vehicle Stopper. There were also briefings on classified S&T programs. There were several unclassified action items (e.g., identify spiral opportunities to accelerate the fielding of active denial technologies) and five classified action items.

The next summit had originally been planned for December 2002 but was canceled and may not be rescheduled. The committee strongly believes that an annual S&T Summit is critical. Although, summits are demanding in terms of preparation and attendance time for the senior leaders, they are worth the effort. The summits appear to be having the desired effect of educating top Air Force leaders on opportunities for enhancing future combat capabilities through the S&T program. The commanders of both AFMC and AFRL indicated that the summits have improved communication and understanding between the S&T community and warfighters. The meetings have also helped ensure that the right S&T projects are being worked to best support warfighters. The result from the first summit—getting the major commands to commit transition funding for ATDs—was a significant step. Action items from the summits also evidence their effectiveness. The scope of this summit activity could be expanded by instituting similar exchanges between the S&T advocate and other constituencies, including OSD, other services, and key congressional members and staff.

Applied Technology Councils

This subsection addresses the statement of task question Are the applied technology councils effective in contributing the input of all levels beneath the senior leadership into coordination, focus, and content of the S&T program?

The Air Force has instituted ATCs to improve the transition of technology from AFRL into applicable weapon systems. ATCs are semiannual meetings of the AFRL commander, the appropriate product center commander(s), and the vice commander of the using command. There are five different ATCs (with Air Combat Command [ACC], Air Mobility Command [AMC], Air Force Special Operations Command [AFSOC], Air Force Space Command [AFSPC], and AFMC). All of the ATCs have met at least four times and will continue to meet.

The ATCs originally started by reviewing the progress and funding on ATD programs being conducted by AFRL. Consistent with the overall aim of the rapid, successful transition of technology into the hands of warfighters, three goals have been established for each ATC: (1) that AFRL have 50 percent of 6.3 funding in ATDs, with the remainder in critical experiments; (2) that an ATC not commission a new ATD or continue funding an existing ATD without commitment by the using command to budget for the funding required to transition the matured technology into a weapon system; and (3) that the applicable SPO director be prepared, together with his or her contractor, to incorporate the matured technology into the weapon system when funding is available.

ATCs have matured and broadened in scope. A Weapon System Capability Plan (WSCP) has been developed for each weapon system. WSCPs track the technology availability dates for each of the emerging technologies and graphically depict the time when the technology will be available for incorporation into the weapon system and the status of required funding.

ATCs appear to be very successful in establishing effective and meaningful communication between the using commands, SPOs at product centers, and AFRL. When the process was initiated, less than 15 percent of the ATDs were fully funded for transition. After four rounds of ATCs, required transition funding has been budgeted for over 50 percent of the ATDs. Some ATDs have been terminated or restructured, and some new ATDs have been commissioned. Using commands, at the top-leadership level, have a greater appreciation for S&T potential and a stronger voice with respect to which ATDs are pursued. Weapon system SPOs have an increased appreciation for the technology thrusts being pursued in AFRL and for which ones using commands would like incorporated into weapon systems. AFRL has developed an increased appreciation for helping to ensure that technology is not only developed but also successfully transitioned to using commands. However, the ATC process has not yet been codified in an Air Force regulation, although one has been drafted.

The ATCs have been a success in two directions—they enhanced AFRL awareness of warfighter needs and the transition of technology, and they improved the MAJCOMs' appreciation of the value of S&T and the processes required. The latter, improving the leadership's appreciation for S&T, is a key to improving the long-term prospects of S&T in the Air Force. This appreciation could be enhanced by extending this process down to the 6.2 level.

Air Force Organizational Structure and S&T Advocate

This subsection addresses two statement of task questions: Does the Air Force organizational structure provide for a sufficiently senior-level advocate of S&T to ensure an ongoing, effective presence of the S&T community during the budget and planning process? Is the designation of the AFMC commander as the S&T budget advocate effective to assure that an adequate budget top line is set?

The Air Force views the principal concern regarding organization and advocacy as "senior leadership's understanding of the need to maintain S&T for the future warfighter needs and advocating a long-range direction for the S&T program" (Schneider, 2002b, chart 13). The Air Force reported action on this concern to the committee and on most of the specific concerns and recommendations relative to it that have been raised by Congress and in previous studies.

Changes described in the present report apply to the organizational structure or to processes employed by the structure. For the changes to provide an "ongoing, effective presence of the S&T community during the budget and planning process," as called out in the question beginning this subsection, those changes must positively influence the Air Force's process for integrating its program and budget submissions.

There exists a widespread perception that S&T advocacy has suffered in comparison with that for other parts of the Air Force program. The committee believes, however, that since the Air Force designated AFMC to program for and advocate S&T (see below), advocacy for S&T has become comparable to that for other major parts of the Air Force program (i.e., it is initially programmed by an Air Force major command with a four-star commander as the principal advocate). During integration of the total Air Force program by Air Force headquarters, the AFMC commander and his staff advocate S&T in the same way that the other major commands advocate their programs. Also, during the integration, S&T is represented in the Air Force corporate structure at the same level in the Office of the Secretary or the Air Staff as are other major parts of the Air Force program.

The way in which S&T resulting from Air Force funding finds its way into Air Force systems may obscure an understanding of its role in the Air Force for maintaining the technological edge. S&T applied in a system is usually the choice of the winning prime contractor, so the S&T "source" is not usually known to personnel beyond those directly involved in the acquisition program.

The committee notes that the shorter acquisition cycle promised by the Air Force's collaborative, spiral development initiative may offer more opportunities for technology insertion, assuming that programs are so structured, as the Air Force states. Such program design requires clever, resourceful people with knowledge of potential technological opportunities and ingenuity. Success requires integrated program and technology planning that effectively bridges the organizational boundary between AFRL and the Air Force product and logistics centers; perhaps the reinvigorated development (capability) planning discussed in this chapter can facilitate such planning, with emphasis on a modular, open systems approach.

While to many, the value of S&T to the Air Force is self-evident, to many others now, the lessons of history could profitably be told. A serious, thorough, and competent effort to educate the officer corps on the history, value, and necessity for S&T may be the most fruitful investment in the long term. One approach to this endeavor would be to task the Air Force history community to document, for reading throughout the Air Force, the technological history of the enablers of current major Air Force capabilities (such as stealth and precision munitions). The objective would be to provide future Air Force planners and leaders with an appreciation of the link between S&T and operational military capabilities. Another approach would be the development of case studies that could be used at the Air War College to enhance the curriculum for all Air Force mid-level officers. Such case studies could also be developed by a few of these students as a "thesis" and/or a research project and then be available as classroom material for the larger group of students.

As a result of pressures on the Air Force budget and resulting impacts on the S&T component of that budget over the past several years, recent studies have called for a senior-level uniformed advocate for the Air Force S&T program. As an indirect result of the recommendations of these studies and a direct result of a recommendation in an Air Force SAB summer study of 2000 (SAB, 2001), the Air Force has recently designated the AFMC commander as its "S&T advocate." The mechanism for this advocacy was the reassignment of S&T POM formulation and submission from SAF/AQ to the AFMC commander.

Previously, the AFRL commander, serving also in the position of Air Force technology executive officer, submitted the S&T POM through SAF/AQ, who served as advocate throughout the Air Force's POM and budget deliberations. Under that arrangement, the AFMC commander still had responsibility for AFRL manpower (submitted as part of the AFMC POM) and infrastructure (where AFRL military construction [MILCON] projects were prioritized and submitted as part of the AFMC submission). Under the new arrangement, about 2 years ago S&T POM responsibility was shifted from SAF/AQ to AFMC. Thus, the S&T POM is now submitted as part of the overall AFMC POM, and the AFMC commander has become the advocate for the S&T budget.

Since this change has been operative for only one full Air Force POM cycle, it is too early to judge its effectiveness fully. However, the rationale for the change seems well grounded, and preliminary indications are that it is already having positive effects.

There are at least four reasons why designating the AFMC commander as the S&T advocate is sound. First, the AFMC commander is a four-star military executive who has peer relationships with his four-star counterparts in the Air Force's warfighting commands. Second, with this change, the AFMC commander now has responsibility for the full set of S&T resource-related decisions—S&T budget, laboratory manpower, and laboratory infrastructure. As a result, he can formulate an integrated set of investment strategies that were otherwise divided between different organizational chains of command and different POM and budget submissions. Third, the AFMC commander participates in senior forums with his four-star counterparts during which investment deliberations and decisions are often shaped (e.g., the Corona series of Air Force senior leadership meetings). Fourth, as a senior officer, the AFMC commander has the opportunity to be especially effective in advocating Air Force S&T outside the Air Force to key decision-making and policy organizations, such as OSD and the Congress. This combination of factors positions the AFMC commander to be a most logical and effective advocate of S&T within and outside the Air Force.

A potential downside to assigning S&T POM responsibility to the AFMC commander is that a future commander with marginal appreciation for the S&T mission could, when faced with budget shortfalls in other AFMC organizations (e.g., near-term needs of product, test, or logistics centers) be less protective of the S&T budget and use part of it to fix such shortfalls during preparation of the overall AFMC POM submission. External checks and balances (e.g., corporate Air Force, OSD, and congressional review of POM submissions) should help mitigate this possibility.

It has been suggested that the Air Force Vice Chief of Staff should be considered as an alternative to the AFMC commander as the S&T advocate. However, current roles and missions of the Vice Chief explicitly preclude this position from serving as an advocate for any program during the POM process (S&T is a budget line item and therefore considered a program). More specifically, the Vice Chief chairs the Air Force Council, which adjudicates the Air Force POM and budget process, and therefore cannot serve as an advocate for any program that the council would consider during the adjudication process.

FINDINGS AND RECOMMENDATIONS

Scientific and Engineering Workforce

Finding 3-1. Problems within the Department of Defense's scientific and engineering (S&E) workforce have been aggravated in the past 15 years by policies that have adversely affected the workforce and resulted in a crisis in the Air Force S&E military and civilian workforce. Air Force plans, to be implemented in FY 2003, may help alleviate these problems; however, absent action by the Secretary of Defense, present plans are unlikely to halt the trends in the S&E workforce, described in dire terms in numerous studies and reports as well as in presentations made to this committee (Schneider, 2002b). Steps and processes being adopted by the Air Force are but small, incremental steps.

Finding 3-2. Although Congress has provided by law for the capability to help with the S&E workforce problem, administrative difficulties within the Office of the Secretary of Defense have prevented the implementation of the needed measures. Based on experience to date, it appears that only direction by the Secretary of Defense will override the interests of various agencies which, from their perspectives, have a legitimate role in "protecting the current personnel system." Critical constraints, until gone or reduced, will not allow the service laboratories to compete effectively for S&E personnel. Said another way, the committee believes that it is not an overstatement to conclude that the need to address the S&E workforce problem is a situation in which national security concerns merit the direct involvement of the Secretary of Defense.

Finding 3-3. The committee found no evidence of a comprehensive plan or methodology in place for the management of long-term military and civilian S&E workforce requirements.

Recommendation 3-1. The Secretary of Defense should immediately direct the implementation of the provisions of Section 1114 of the FY 2001 National Defense Authorization Act (P.L. 106-398) so that Department of Defense laboratory directors have the ability to shape their workforces. The Air Force Secretary and Chief of Staff should ensure rapid execution of these provisions.

Recommendation 3-2. The Air Force should conduct a comprehensive review of requirements for military and civilian S&E-trained people across the Air Force, including laboratories and system program offices, and establish a system for long-term management of the S&E workforce.

Planning

Finding 3-4. The Air Force complied with the requirements of Section 252 of the FY 2001 National Defense Authorization Act (P.L. 106-398). The committee found agreement among the participants that the Section 252 review was an effective aid in helping to define the candidate investment portfolio. Additional refinements beyond Section 252 in the planning methodology are needed to influence the S&T portfolio. Many possibilities for refinement exist, such as those discussed in the text.

Finding 3-5. The applied technology councils (ATCs) provide a powerful mechanism for reviewing the 6.3 S&T activity that involves the customers. The 6.2 activities would also benefit from a similar annual review that engaged outside stakeholders such as the warfighters and major commands. Such a review should include activities marginally above and below the nominal budget limit.

Finding 3-6. The development (capability) planning process is critical to successful S&T investment for meaningful warfighting capability and therefore is critical to our national defense. The committee believes that the Air Force Materiel Command recognizes the need. However, the Air Force is a long way from having viable development (capability) planning. This deficit is especially clear in the area of broad-gauged concept planning at the level of "systems of systems."

Recommendation 3-3. The Air Force should take advantage of the framework provided by Section 252 of the FY 2001 National Defense Authorization Act as an important step in its overall S&T planning process. Further legislation is not required.

Recommendation 3-4. For future use, the Air Force should refine the FY 2001 National Defense Authorization Act Section 252 framework to develop the long-term plan that the Air Force sees as the overarching concern. In doing this, the Air Force should seriously consider the many suggestions offered by this committee, but giving special attention to the following: (1) implementing the "lessons learned" that were briefed to the committee by personnel from the office of the Deputy Assistant Secretary of the Air Force for Science, Technology, and Engineering; (2) fully incorporating the planning process into the planning, programming, and budgeting system, specifically with regard to timing and the application of fiscal constraints, especially for long-term challenges; (3) revising the planning categories to cover mid-term challenges (5 to 15 years) and long-term challenges (15 years and beyond); and (4) aligning the framework to the current Air Force strategic planning process by using the ConOps Task Forces framework in lieu of the short-term objectives framework.

Recommendation 3-5. The Air Force Research Laboratory should institute a review process for 6.2 and 6.3 critical experiments that engages the warfighters and major commands.

Recommendation 3-6. The Air Force should reconstitute a strong, crosscutting development/capability planning organization staffed by experienced individuals with broad backgrounds and in-depth expertise (combined operational and S&T experience would be highly desirable).

Advocacy and Visibility

Finding 3-7. S&T Summits have been effective in improving dialogue among S&T people, commanders of major commands, and key staff personnel. While it is still too early to determine the longevity of these summits, there are grounds for concern, since the December 2002 summit was canceled and may not be rescheduled. Although summits are demanding in terms of preparation and attendance time for the senior leaders, they are worth the effort. Indeed, the scope of this effort could be expanded by instituting similar exchanges between the S&T advocate and other constituencies, including the Office of the Secretary of Defense, other services, and key congressional members and staff.

Finding 3-8. The applied technology council (ATC) process has been very beneficial. Weapon System Capability Plans (WSCPs) provide a readily understandable guide to indicate the points at which technologies will be able to be introduced into a weapon system if funding remains available. However, the ATC process has not yet been codified in an Air Force regulation, although one has been drafted. Completing codification soon, including WSCPs, would help institutionalize the process.

Finding 3-9. Designation of the Air Force Materiel Command commander as the S&T advocate appears to be a positive change in terms of both higher visibility and stronger advocacy of the S&T program to both internal stakeholders (the Air Force) and external stakeholders (other services, Office of the Secretary of Defense, and Congress). Actual effectiveness can be measured over time by metrics such as the level and trend of the S&T budget relative to prior years and the Air Force budget and amount of technology transitioned from the laboratory to Air Force acquisition programs.

Recommendation 3-7. The important S&T Summit process should be continued on an annual basis, arranged over time to cover the full range of S&T categories. The summits should be aligned to best influence the budget process.

Recommendation 3-8. The applied technology council process, along with Weapon System Capability Plans, should be continued and codified by regulation.

Recommendation 3-9. The commander of the Air Force Materiel Command should continue as the Air Force S&T advocate. A mechanism should be instituted for the S&T advocate to brief the S&T plan to and receive feedback from the combatant commanders, the Office of the Secretary of Defense, other service personnel, key congressional staff, and members of Congress, if practical; this mechanism should include the possibility of briefing the results of S&T Summits as well.

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Appendixes

Appendix A

Section 253, National Defense Authorization Act for Fiscal Year 2002 (Public Law 107-107)

SEC. 253. STUDY AND REPORT ON EFFECTIVENESS OF AIR FORCE SCIENCE AND TECHNOLOGY PROGRAM CHANGES.

(a) REQUIREMENT.—The Secretary of the Air Force, in cooperation with the National Research Council of the National Academy of Sciences, shall carry out a study to determine how the changes to the Air Force science and technology program implemented during the past two years affect the future capabilities of the Air Force.

(b) MATTERS STUDIED.—(1) The study shall review and assess whether such changes as a whole are sufficient to ensure the following:

(A) That the concerns about the management of the science and technology program that have been raised by Congress, the Defense Science Board, the Air Force Science Advisory Board, and the Air Force Association have been adequately addressed.

(B) That appropriate and sufficient technology is available to ensure the military superiority of the United States and counter future high-risk threats.

(C) That the science and technology investments are balanced to meet the near-, mid-, and long-term needs of the Air Force.

(D) That technologies are made available that can be used to respond flexibly and quickly to a wide range of future threats.

(E) That the Air Force organizational structure provides for a sufficiently senior level advocate of science and technology to ensure an ongoing, effective presence of the science and technology community during the budget and planning process.

(2) In addition, the study shall assess the specific changes to the Air Force science and technology program as follows:

(A) Whether the biannual science and technology summits provide sufficient visibility into, and understanding and appreciation of, the value of the science and technology program to the senior level of Air Force budget and policy decision-makers.

(B) Whether the applied technology councils are effective in contributing the input of all levels beneath the senior leadership into the coordination, focus, and content of the science and technology program.

(C) Whether the designation of the commander of the Air Force Materiel Command as the science and technology budget advocate is effective to ensure that an adequate Air Force science and technology budget is requested.

(D) Whether the revised development planning process is effective to aid in the coordination of the needs of the Air Force warfighters with decisions on science and technology investments and the establishment of priorities among different science and technology programs.

(E) Whether the implementation of section 252 of the Floyd D. Spence National Defense Authorization Act for Fiscal Year 2001 (as enacted into law by Public Law 106–398; 114 Stat. 1654A–46) is effective to identify the basis for the appropriate science and technology program funding level and investment portfolio.

(c) REPORT.—Not later than May 1, 2003, the Secretary of the Air Force shall submit to Congress the results of the study.

Appendix B

Section 252, National Defense Authorization Act for Fiscal Year 2001 (Public Law 106-398)

SEC. 252. AIR FORCE SCIENCE AND TECHNOLOGY PLANNING.

(a) REQUIREMENT FOR REVIEW.—The Secretary of the Air Force shall conduct a review of the long-term challenges and short-term objectives of the Air Force science and technology programs. The Secretary shall complete the review not later than one year after the date of the enactment of this Act.

(b) MATTERS TO BE REVIEWED.—The review shall include the following:

(1) An assessment of the budgetary resources that are being used for fiscal year 2001 for addressing the long-term challenges and the short-term objectives of the Air Force science and technology programs.

(2) The budgetary resources that are necessary to address those challenges and objectives adequately.

(3) A course of action for each projected or ongoing Air Force science and technology program that does not address either the long-term challenges or the short-term objectives.

(4) The matters required under subsection (c)(5) and (d)(6).

(c) LONG-TERM CHALLENGES.—(1) The Secretary of the Air Force shall establish an integrated product team to identify high-risk, high-payoff challenges that will provide a long-term focus and motivation for the Air Force science and technology programs over the next 20 to 50 years following the enactment of this Act. The integrated product team shall include representatives of the Office of Scientific Research and personnel from the Air Force Research Laboratory.

(2) The team shall solicit views from the entire Air Force science and technology community on the matters under consideration by the team.

(3) The team—

(A) shall select for consideration science and technology challenges that involve—

(i) compelling requirements of the Air Force;

(ii) high-risk, high-payoff areas of exploration; and

(iii) very difficult, but probably achievable, results; and

(B) should not select a linear extension of any ongoing Air Force science and technology program for consideration as a science and technology challenge under subparagraph (A).

(4) The Deputy Assistant Secretary of the Air Force for Science, Technology, and Engineering shall designate a technical coordinator and a management coordinator for each science and technology challenge identified pursuant to this subsection. Each technical coordinator shall have sufficient expertise in fields related to the challenge to be able to identify other experts in such fields and to affirm the credibility of the challenge. The coordinator for a science and technology challenge shall conduct workshops within the relevant scientific and technological community to obtain suggestions for possible approaches to addressing the challenge and to identify ongoing work that addresses the challenge, deficiencies in current work relating to the challenge, and promising areas of research.

(5) In carrying out subsection (a), the Secretary of the Air Force shall review the science and technology challenges identified pursuant to this subsection and, for each such challenge, at a minimum—

(A) consider the results of the workshops conducted pursuant to paragraph (4); and

(B) identify any work not currently funded by the Air Force that should be performed to meet the challenge.

(d) SHORT-TERM OBJECTIVES.—(1) The Secretary of the Air Force shall establish a task force to identify short-term technological objectives of the Air Force science and technology programs. The task force shall be chaired by the Deputy Assistant Secretary of the Air Force for Science, Technology, and Engineering and shall include representatives of the Chief of Staff of the Air Force and the specified combatant commands of the Air Force.

(2) The task force shall solicit views from the entire Air Force requirements community, user community, and acquisition community.

(3) The task force shall select for consideration short-term objectives that involve—

(A) compelling requirements of the Air Force;

(B) support in the user community; and

(C) likely attainment of the desired benefits within a five-year period.

(4) The Deputy Assistant Secretary of the Air Force for Science, Technology, and Engineering shall establish an integrated product team for each short-term objective identified pursuant to this sub-section. Each integrated product team shall include representatives of the requirements community, the user community, and the science and technology community with relevant expertise.

(5) The integrated product team for a short-term objective shall be responsible for—

(A) identifying, defining, and prioritizing the enabling capabilities that are necessary for achieving the objective;

(B) identifying deficiencies in the enabling capabilities that must be addressed if the short-term objective is to be achieved; and

(C) working with the Air Force science and technology community to identify science and technology projects and programs that should be undertaken to eliminate each deficiency in an enabling capability.

(6) In carrying out subsection (a), the Secretary of the Air Force shall review the short-term science and technology objectives identified pursuant to this subsection and, for each such objective, at a minimum—

(A) consider the work of the integrated product team conducted pursuant to paragraph (5); and

(B) identify the science and technology work of the Air Force that should be undertaken to eliminate each deficiency in enabling capabilities that is identified by the integrated product team pursuant to subparagraph (B) of that paragraph.

(e) COMPTROLLER GENERAL REVIEW.—(1) Not later than 90 days after the Secretary of the Air Force completes the review required by subsection (a), the Comptroller General shall submit to Congress a report on the results of the review. The report shall include the Comptroller General's assessment regarding the extent to which the review was conducted in compliance with the requirements of this section.

(2) Immediately upon completing the review required by subsection (a), the Secretary of Defense shall notify the Comptroller General of the completion of the review. For the purposes of paragraph (1), the date of the notification shall be considered the date of the completion of the review.

Appendix C

Biographical Sketches of Committee Members

Alan H. Epstein, *Chair,* is a member of the National Academy of Engineering and is the R.C. Maclaurin Professor in the Department of Aeronautics and Astronautics at the Massachusetts Institute of Technology and director of the Gas Turbine Laboratory. Airbreathing propulsion and gas turbines are his primary areas of technical interest. Other areas of activity have included turbomachinery noise and the development of new instrumentation technologies. Most recently, he has been working to develop micro electrical and mechanical systems (MEMS)-based shirt-button-sized gas turbine and rocket engines, manufactured with semiconductor industry fabrication technology from ceramic materials. He is a fellow of the American Institute of Aeronautics and Astronautics and a member of the American Association for the Advancement of Science and of the American Society of Mechanical Engineers. He is a member of the National Research Council's Air Force Science and Technology Board. He was selected to serve on this committee for his expertise in laboratory management, test and evaluation, and aero/astronautics and aero/thermodynamics.

George K. Muellner (USAF Ret.), *Vice Chair,* is senior vice president for Air Force Systems, the Boeing Company. Prior to this assignment, he was the president of Boeing Company Phantom Works. Previously, he was principal deputy, Office of the Assistant Secretary of the Air Force for Acquisition. He served as the Air Force military acquisition executive in carrying out the management responsibilities for the Air Force acquisition system, including direction, guidance, and supervision over all matters pertaining to the formulation, review, approval, and execution of plans, policies, and programs relative to acquisition. Additionally, he was designated as the Air Force chief information officer. The general entered the Air Force through the Reserve Officer Training Corps program at the University of Illinois. Most of his career was spent as a fighter pilot, fighter weapons instructor, and test pilot, with more than 5,300 hours in F-4, A-7, F-15, and F-16 aircraft. He completed 690 combat missions in Vietnam flying the F-4, and during Operation Desert Storm he commanded the Joint Stars deployment, logging another 50 combat sorties. He has commanded a classified test squadron, the Joint Stars Squadron, and a tactical fighter wing. As director of requirements at Air Combat Command, he orchestrated the operational requirements for all of the combat air forces and then became the mission area director for tactical, C3 (command, control, and communications), and weapons programs for the assistant secretary of the Air Force for acquisition. As the program executive officer for the Joint Advanced Strike Technology Program, he created this joint service development activity, which led to the Joint Strike Fighter Program. He was selected to serve on this National Research Council committee for his expertise in military acquisition, procurement, research, and technology; industrial management; laboratory management; test and evaluation; space science; systems development and management; aero/astronautics and aero/thermodynamics; cost analysis; systems analysis; computer and communications technologies; and Air Force organization and management.

Minoru S. Araki, a member of the National Academy of Engineering, is a retired president of Lockheed-Martin Missiles and Space. He joined Lockheed Missiles and Space Company in 1958 as a senior scientist. Subsequent promotions earned him positions as assistant chief engineer, development; director, systems engineering; director, advanced systems, Space Systems Division; vice president, Space Systems Division, advanced programs and development; vice president and program manager of the division's Milstar programs; vice president and general manager of Space Systems Division; president and general manager of Space Systems Division; vice president of Lockheed Corporation; executive vice president of Lockheed's Missiles and Space Systems Group; and president of Lockheed-Martin Missiles and Space. His research interests include communication satellite applications to government and commercial missions, satellite remote-sensing missions, global positioning satellite missions, and ballistic missile defense. He is a fellow of the American Astronautical Society and a member of the American Institute of Aeronautics and Astronautics and of the Institute for Electrical and Electronics Engineers. He was selected to serve on this National Research Council committee for his expertise in military acquisition, procurement, research, and technology; industrial management; test and evaluation; space science; systems development and management; and systems analysis.

Lynn A. Conway, a member of the National Academy of Engineering, is a professor emerita of electrical engineering and computer science (EECS) at the University of Michigan. Prior to joining the University of Michigan, she held positions as a member of the research staff, IBM Corporation; senior staff engineer, Memorex Corporation; visiting associate professor of EECS at the Massachusetts Institute of Technology; research staff member and research manager, Xerox Palo Alto Research Center; and chief scientist and assistant director for strategic computing, Defense Advanced Research Projects Agency. Her areas of interest include computer science and electrical engineering, computer system architecture, artificial intelligence, robotics and automation, microelectronics design methodology, computer-aided design and computer-aided manufacturing and collaboration technology, as well as interdisciplinary innovations in the cross products of these specialties. She is experienced in the leadership and management of advanced research and is adept at engineering education administration. She is a fellow of the Institute for Electrical and Electronics Engineers and a member of the American Association of Artificial Intelligence and of the American Association for the Advancement of Science. She is a member of the National Research Council's (NRC's) Air Force Science and Technology Board, and in the past has served as a member of the Air Force Scientific Advisory Board and as a member of the Board of Visitors at the U.S. Air Force Academy (presidential appointment). She was selected to serve on this NRC committee for her expertise in military acquisition, procurement, research, and technology; laboratory management; computer and communications technologies; microelectronics; artificial intelligence; and robotics.

William H. Crabtree is president of BC Associates in Cincinnati, Ohio. His company provides management and technical consulting services to government and to the aerospace industry. His areas of interest include acquisition management, orbital launch systems, space communications systems, satellite systems, precision missile weapons systems, and ballistic missile systems. He has served in a variety of significant Air Force management positions related to these areas. As a consultant, his company has served industry by conducting acquisition management courses, participating in proposal reviews, and suggesting business development strategies. He has received numerous awards and commendations and is member of several honor societies. He was selected to serve on this National Research Council committee for his expertise in military acquisition, procurement, research, and technology; space science; systems development and management; systems analysis; and control theory.

Natalie W. Crawford, a member of the National Academy of Engineering, is vice president and director of Project AIR FORCE at the RAND Corporation. She joined RAND in 1964 as a member of the technical staff and advanced though several positions, including senior staff member and project leader, associate program director, program director, and Project AIR FORCE associate director. She has served as a vice chair and co-chair of the Air Force Scientific Advisory Board. She is a member of the American Institute of Aeronautics and Astronautics. She was selected to serve on this National Research Council committee for her expertise in conventional stand-off weapons; night/adverse-weather attack capabilities; tactical aircraft;

aircraft survivability; munitions and targets; tactical air requirements; avionics; aero performance; survivability; electronic combat; weapons effects; off-board sensor support to combat operations; power projection force structure and assessments; theater air defense; force modernization; and space systems.

Irwin Dorros, a member of the National Academy of Engineering (NAE), is a retired executive vice president, Technical Services, Telcordia Technologies, Inc., and president of Dorros Associates. He is a fellow of the Institute for Electrical and Electronics Engineers. As executive vice president, he was responsible for the entire work program of Bellcore. He headed a research and development organization of 5,000 scientists, engineers, and software specialists, providing for the seven Regional Bell Companies: research, systems engineering, software design, quality assurance, systems analysis, technical standards planning, network planning, and other technical services. He was responsible for an annual budget greater than $1 billion and was a member of the Bellcore board of directors. He has broad interests in the fields of telecommunications and information networking. In recent years, he has given increasing attention to the deployment and business aspects of these disciplines. He is a fellow of the Institute for Electrical and Electronics Engineers. He is the NAE Section 7, Electrical Engineering, liaison to the National Research Council (NRC). He was selected to serve on this NRC committee for his expertise in industrial management, laboratory management, test and evaluation, systems development and management, systems analysis, and computer and communications technologies.

Delores M. Etter, a member of the National Academy of Engineering, joined the electrical engineering faculty at the U.S. Naval Academy on August 1, 2001, as the first recipient of the Office of Naval Research Distinguished Chair in Science and Engineering. Her research interests are in adaptive signal processing, speech and speaker recognition, digital filter design, and software engineering. Her educational interests include the development of collaborative experiments in virtual teaming of students using the Internet. From June 1998 through July 2001, Dr. Etter served as the Deputy Under Secretary of Defense for Science and Technology. In that position, she was responsible for Defense science and technology strategic planning, budget allocation, and program execution and evaluation for the $9 billion per year Department of Defense (DoD) Science and Technology Program. Her previous positions include faculty positions at the University of Colorado, Boulder; the University of New Mexico; and Stanford University. She is a member of the Defense Science Board and a former member of the Naval Research Advisory Committee. She is a fellow of the Institute for Electrical and Electronics Engineers, a fellow of the American Association for the Advancement of Science, and a fellow of the American Society for Engineering Education. She is a member of the National Research Council's (NRC's) Air Force Science and Technology Board. She was selected to serve on this NRC committee for her expertise in military acquisition, procurement, research, and technology; systems development and management; systems analysis; computer and communications technologies; and academic research.

Ilan Kroo is a professor of aeronautics and astronautics at Stanford University. Before returning to Stanford as a member of the aero/astro faculty, he worked in the Advanced Aerodynamic Concepts Branch at the National Aeronautics and Space Administration's Ames Research Center for 4 years. His research in aerodynamics and multidisciplinary design optimization includes the study of innovative airplane concepts. He has participated in the design of UAVs, flying pterosaur replicas, America's Cup sailboats, and high-speed research aircraft. In addition to his research and teaching interests, he is director of a small software company and is an advanced cross-country hang glider pilot. He is a fellow of the American Institute of Aeronautics and Astronautics. He was selected to serve on this National Research Council committee for his expertise in industrial management, aero/astronautics and aero/thermodynamics, and systems analysis.

Robert G. Loewy, a member of the National Academy of Engineering, is the William R.T. Oakes Professor and chair of the School of Aerospace Engineering at the Georgia Institute of Technology. He has served as chief scientist of the Air Force, as chairman of the Air Force Scientific Advisory Board and of the Aeronautical Systems Division Advisory Group, and is conversant with scientific and technical issues currently facing the service. His background includes aerospace science, space science, aircraft design, flight dynamics, and other applicable disciplines. He served as a member of the recently concluded F-22 live fire test study committee, whose report was extremely well received by Congress and the Department of Defense. He is a member of the National Research Council's (NRC's) Air Force Science and Technology Board. He was selected to serve on this NRC committee for his expertise in military acquisition, procurement, research, and technology; test and evaluation; systems development and management; aero/astronautics and aero/thermodynamics; and systems analysis.

R. Noel Longuemare, a member of the National Academy of Engineering, serves as a private consultant. He retired from his previous position of Principal Deputy Under Secretary of Defense for Acquisition and Technology after serving for 4 years. For two 6-month periods, he also served as Acting Under Secretary of Defense for Acquisition and Technology. In these capacities he was responsible for all matters relating to Department of Defense acquisition. Prior to his appointment by President Clinton, he was a corporate vice president and general manager of the Systems Development and Technology Divisions at the Westinghouse Electronic Systems Group. He played a leading role in the development of modern radar and avionics systems for airborne and land mobile applications. He is a fellow of the Institute for Electrical and Electronics Engineers, a fellow of the American Association for the Advancement of Science, and a fellow of the American Institute of Aeronautics and Astronautics. He is vice chair of the National Research Council's (NRC's) Air Force Science and Technology Board. He was selected to serve on this NRC committee for his expertise in military acquisition, procurement, research, and technology; industrial management; and systems development and management.

Robert J. Patton, a member of the National Academy of Engineering, currently serves as a private consultant. He is a retired senior vice president of business development, vice president of aircraft development engineering, and chief engineer/systems engineering development at LTV Aerospace Products Group. He has also held positions as director of manufacturing control at General Dynamics Electric Boat Division, director of B-1A systems engineering at the U.S. Air Force Aeronautical Systems Division, and program director of the FB-111A at General Dynamics Fort Worth Division. He is a fellow of the American Institute of Aeronautics and Astronautics. He was selected to serve on this National Research Council committee for his expertise in military acquisition, procurement, research, and technology; industrial management; test and evaluation; space science; systems development and management; aero/astronautics and aero/thermodynamics; and systems analysis.

Richard R. Paul (USAF Ret.) is vice president of strategic development for Phantom Works, The Boeing Company, Seattle, Washington. (Phantom Works is Boeing's research and development organization, dedicated to advancing the company's competitiveness through technology development, process improvement, and new product development.) He joined Boeing in October 2000, after 33 years with the Air Force. During his Air Force career, he served in two Air Force laboratories, at a product center, two major command headquarters, Headquarters U.S. Air Force in the Pentagon, and on a joint staff assignment. In his last assignment, he served both as the Air Force technology executive officer and as the commander of the Air Force Research Laboratory. General Paul received a bachelor's degree in electrical engineering from the University of Missouri at Rolla (UMR) and a master's degree in electrical engineering from the Air Force Institute of Technology and was recently awarded a professional degree in electrical engineering by UMR. He is also a graduate of the Air Command and Staff College at Maxwell Air Force Base, Alabama; the Naval War College at Newport, Rhode Island; and the Defense Systems Management College's Program Management Course at Fort Belvoir, Virginia. He is currently a member of the National Research Council's (NRC's) Air Force Science and Technology Board and has served as an ad hoc advisor to the Air Force Scientific Advisory Board. He is also a director on the UMR Alumni Association board of directors, a member of the UMR Academy of Electrical Engineering, a member of the UMR dean of engineering's Advisory Council, and a recipient of the UMR Alumni Merit Award.

George A. Paulikas is a retired executive vice president of the Aerospace Corporation. His 37-year career there included assignments as a member of the technical staff, department head, laboratory director, vice president, group vice president, and senior group vice president, before he became executive vice president in 1992. He has been at the forefront of advances in space science and space technology, making innumerable technical contributions to Air Force and National Reconnaissance Office national security space systems such as Defense Support Program, Defense Satellite Communications System, Global Positioning System, Defense Meteorological Satellite Program, and Milstar. He has served as a member of the Air Force Scientific Advisory Board, the Naval Studies Board, and the National Research Council's (NRC's) Defense Space Technology Committee. He currently serves on the NRC Space Studies Board. He has been a consultant to the Defense Science Board and has served as a trustee of the California Science Center and the Los Angeles Area Council of the Boy Scouts of America. He is a fellow of the American Physical Society, a fellow of the American Institute of Aeronautics and Astronautics, and a member of the American Geophysical Union. He was selected to serve on this NRC committee for his expertise in military space system acquisition, procurement, research, and technology; laboratory management; test and evaluation; space science; space systems planning development and management; and aero/astronautics and aero/thermodynamics.

Robert F. Raggio (USAF Ret.) is the executive vice president of Dayton Aerospace, Inc., a technical and management consulting firm to the aerospace industry and government. Previously, he was commander of the U.S. Air Force Aeronautical Systems Center at Wright-Patterson Air Force Base, Ohio. He commanded the Air Force's largest acquisition center, which is responsible for the procurement of all aeronautical weapon systems; employed a technical and managerial workforce of 12,000; and managed an annual budget of $10 billion. During his Air Force career, Lt. Gen. Raggio served in a variety of operational and acquisition positions of responsibility, including that of C-141 aircraft commander, rescue helicopter commander in Vietnam and Thailand, test pilot, and test wing commander. He accumulated more than 3,200 flying hours in 24 different types of aircraft, including 150 combat missions. He also served in the Air Force Legislative Liaison office as the primary focal point and interface between members of Congress and the Air Force on weapon system issues. He was the program director of several aircraft systems, including the F-22 Raptor air dominance fighter. As the program executive officer for fighters and bombers, his acquisition responsibilities were expanded to include the F-15, F-16, F-117, B-1, and B-2 programs. He was selected to serve on this National Research Council committee for his expertise in military acquisition, procurement, research, and technology; industrial management; test and evaluation, systems development and management; and Air Force organization and management.

Eli Reshotko, a member of the National Academy of Engineering, is the Kent H. Smith Professor Emeritus of Engineering at Case Western Reserve University. He is a fellow of the American Academy of Mechanics, a fellow of the American Association for the Advancement of Science, a fellow of the American Institute of Aeronautics and Astronautics, a fellow of American Physical Society, and a fellow of the American Society of Mechanical Engineers. He is coauthor of more than 100 publications and is affiliated with many task forces, committees, and governing boards, on many of which he serves as chair. His area of expertise is viscous effects in external and internal aerodynamics, two-dimensional and three-dimensional compressible boundary layers and heat transfer, stability and transition of viscous flows—both incompressible and compressible—and low drag technology for aircraft and underwater vehicles. He was selected to serve on this National Research Council committee for his expertise in research and technology, test and evaluation, and aero/astronautics and aero/thermodynamics.

Alton D. Romig, Jr., a member of the National Academy of Engineering, is chief technology officer and vice president of science and technology and partnerships at Sandia National Laboratories. He leads and manages research, development, and engineering in nanosciences, materials and process sciences, microelectronics/microsystems and optoelectronics, high-performance computing, modeling and simulation, advanced manufacturing, batteries, explosive components, and plasma physics. He has received numerous honors, holds two patents, has published more than 160 technical publications, and is the coauthor of three textbooks. He is past president of the American Society for Metals (ASM, International) and other professional groups. He has received a number of prestigious awards, including the Burton Medal and the K.F.J. Heinrich Award. He was selected to serve on this National Research Council committee for his expertise in laboratory management.

Appendix D

Guest Speakers' Presentations to the Committee

MEETING 1, WASHINGTON, D.C., MAY 30-31, 2002

Congressional Concerns	SASC/Carolyn Hanna
	HASC/Steve Ansley
Section 253 Overview	SAF/AQR/Henk Ruck
Recommendation Database	SAF/AQRT/Col Greg Schneider
Management Concerns	SAF/AQRT/Col Greg Schneider
S&T Planning Review	SAF/AQRT/Lt Col Jim Brandt
AF S&T Investment	AFRL/XPP/Greg Rubertus
AF Corporate Board/Process and S&T	SAF/AQX/Lt Col Rob Clarke

MEETING 2, DAYTON, OHIO, JUNE 27-28, 2002

Development Planning	AFMC/DRX/Col Diana Schulz
Applied Technology Councils	ASC/AA/Tom Graves
	AFRL/XPA/Col Brian Jones
	ASC/GRX/Col Mark Donahue
Technology Availability and Flexibility	AFRL/XP/Bill Borger
Turbine Engine Technology	AFRL/PR/Lt Col Jim Nees
Air Force S&T Plan	AFRL/CC/Maj Gen Paul Nielsen
Air Force S&T Program Advocacy	AFMC/CC/Gen Les Lyles

MEETING 3, WASHINGTON, D.C., AUGUST 22-23, 2002

Corporate AF Interaction with Air Force S&T Programs	AF/XP/Maj Gen Gary Heckman
DARPA Approach to S&T Management	DARPA Director/Tony Tether
Air Force S&T Summits	SAF/AQR/Jim Engle
Wright Brothers Institute	ASC/CD/Vince Russo
Army S&T Accelerating the Pace of Transformation	ASA(ALT)/Mike Andrews
AF S&E Functional Manager Perspective	SAF/AQRE/Col Paul Coutee
Defense S&T Investment Focus	ODDR&E (P&P)/Bob Baker
S&T—A Warfighter's Perspective	ACC/XP/Brig Gen Joe Stein
S&T Community in Crisis	NRAC/Skip Lackie and Mike Marshall

How ONR Does S&T for the Department of the Navy	CNR/RADM Jay Cohen
AFSPC Perspective	AFSPC/XPX/Col Jim Shumate

MEETING 4, WOODS HOLE, MASSACHUSETTS, OCTOBER 22-23, 2002

AF SAB Review of AF S&T Program Quality	AF SAB/Bob Selden

MEETING 5, WASHINGTON, D.C., DECEMBER 9-10, 2002

Writing session only; no speakers

Appendix E

Summary of Concerns About the Air Force S&T Program

The concerns that have been raised by Congress and others about the Air Force S&T program are summarized in the sections that follow.

CONGRESSIONAL CONCERNS

During the early to mid-1990s, total annual Department of Defense (DoD) funding declined. Total annual Air Force funding declined as well, as did total annual Air Force science and technology (S&T) funding. Along with funding declines, personnel levels also declined.

During the mid- to late 1990s, Congress became increasingly concerned about the Air Force S&T program. Congress expressed these concerns in a series of annual defense authorization acts starting with the fiscal year (FY) 1999 National Defense Authorization Act—Public Law (P.L.) 105-262, Strom Thurmond National Defense Authorization Act for Fiscal Year 1999 (U.S. Congress, 1998).

Section 214 of the FY 1999 National Defense Authorization Act expressed the sense of Congress regarding aspects of the defense S&T program. Some of the concerns expressed were about the DoD S&T program as a whole, including the Air Force S&T program, and some were specifically about the Air Force program. Included were the following: Congress maintained that the Secretary of Defense should have as an objective to increase the defense S&T budget in real terms by at least 2 percent per year for each of the fiscal years 2000 through 2008; Congress said that the Secretary of each military department should ensure that a senior official in the department holds an appropriate title and responsibility for S&T and that S&T receives priority and leadership attention equal to that received by systems acquisition; and Congress stated that the Secretary of each military department should take appropriate steps to ensure that sufficient numbers of officers and civilian employees in the department possess advanced technical degrees. In particular, Congress was concerned that the Secretary of the Air Force take appropriate measures to ensure that sufficient numbers of scientists and engineers (S&Es) were maintained to address the technological challenges faced in the areas of air, space, and supporting information technology.

Regarding the areas of air, space, and supporting information technology, Section 214 required the Secretary of Defense to conduct a study on the minimum requirements for maintaining a sufficient technology base and on the required S&E workforce. This study was aimed at the Air Force S&T program as the primary component of the DoD program in the three technology areas (U.S. Congress, 1998).

A year later, Section 212 of the FY 2000 National Defense Authorization Act (P.L. 106-65) again expressed the sense of Congress regarding the defense S&T program. Congress believed that the Secretary of Defense had failed to comply with the 2 percent real growth objective of Section 214 in the FY 1999 act, especially the Air Force S&T program, thus jeopardizing the stability of the defense technology base and increasing the risk of failure to maintain technological superiority in future weapon systems. Section 212 repeated Congress's belief that the Secretary of Defense should have 2 percent annual S&T funding real growth as an objective, this time for each of the fiscal years

2001 through 2009. For each fiscal year for which the objective was not met, Section 212 required the Secretary of Defense to explain why the objective was not met and to certify that failure to meet the objective would not jeopardize the stability of the defense technology base or increase the risk of failure to maintain technological superiority in future weapon systems. Finally, Section 212 required the Defense Science Board to assess the effect of failure to comply (U.S. Congress, 1999).

In Section 252 of the FY 2001 National Defense Authorization Act, Congress required the Secretary of the Air Force to conduct a review of the long-term challenges and short-term objectives of the Air Force S&T program (see Appendix B in this report). In addition to requiring the Air Force to identify the long-term challenges and short-term objectives for its S&T program, Section 252 required the Air Force to assess the budgetary resources necessary to adequately address those challenges and objectives (U.S. Congress, 2000). Section 252 reflected Congress's continuing concern about the level of funding for the Air Force S&T program and its concern about the planning of the Air Force S&T program.

The S&T planning review required by Section 252, one of the specific items that the committee was asked to assess, is discussed in the chapters of this report.

Sections 251 through 253 of the FY 2002 National Defense Authorization Act (P.L. 107-107) were entitled the "Air Force Science and Technology for the 21st Century Act." In this act, Congress stated that the Secretary of the Air Force should continue to improve efforts to ensure that Air Force S&T is represented and considered at all levels of Air Force program planning and budgetary decision making, that S&T advocacy is institutionalized across all levels of Air Force management in a manner that is not person dependent, and that the value of S&T is made apparent to warfighters by linking warfighter needs to S&T decisions. Congress stated that every 5 years the Secretary of the Air Force should conduct a review of long-term challenges and short-term objectives consistent with the Section 252 review described previously. Congress stated that the Secretary of the Air Force should elevate the position within the Office of the Secretary of the Air Force that has primary responsibility for S&T program budget and policy decisions. Finally, Congress directed the Secretary of the Air Force to reinstate and implement a revised development planning process (U.S. Congress, 2001). As stated previously, Section 253 of this act (see Appendix A in this report) requested that the National Research Council (NRC) conduct a study of changes that the Air Force has made to its S&T program during recent years.

DEFENSE SCIENCE BOARD

The Defense Science Board (DSB) advises Department of Defense (DoD) leaders on S&T and other technical issues (see Box E-1). In this role, the DSB has conducted numerous studies and has issued reports that deal with or involve the DoD S&T program. Most DSB studies and reports deal with or involve DoD-level or DoD-wide S&T program issues; however, as part of the larger DoD program, the Air Force S&T program is often included in the scope of these reports or is affected by their recommendations. In a briefing to the Committee on Review of the Effectiveness of Air Force Science and Technology Program Changes, the Air Force identified nine recent DSB reports containing recommendations relevant to this study (Schneider, 2002a). Several of these reports were focused on specific technology or mission areas. Two recent DSB reports, however, were particularly pertinent to Air Force S&T program-wide issues.

BOX E-1
Defense Science Board

The Defense Science Board (DSB), composed of members designated from civilian life by the Under Secretary of Defense (Acquisition, Technology and Logistics), advises, in response to taskings, the Secretary of Defense, the Deputy Secretary of Defense, the Under Secretary of Defense (Acquisition, Technology and Logistics), and the Chairman of the Joint Chiefs of Staff on scientific, technical, manufacturing, acquisition process, and other matters of special interest to the Department of Defense. The board is concerned with the pressing and complex technology problems facing the Department of Defense in such areas as research, engineering, and manufacturing, and it ensures the identification of new technologies and new applications of technology in those areas to strengthen national security.

The DSB reports to the Secretary of Defense through the Under Secretary of Defense (Acquisition, Technology and Logistics). DSB reports are subject to Under Secretary and/or Secretary of Defense or Deputy Secretary of Defense approval prior to release to the public.

SOURCE: See <http://www.acq.osd.mil/dsb/> [August 20, 2002].

The first of these was a DSB letter report on the adequacy of the DoD S&T program (DSB, 2000). This report was required by Section 212 of the FY 2000 National Defense Authorization Act, which required the Defense Science Board to assess the effect of the Secretary of Defense's failure to comply with Congress's 2 percent real-growth objective for defense S&T in the FY 2001 budget request. In its response in the letter report, the DSB stated that DoD S&T should be funded at $8.7 billion (3 percent of the total budget request) rather than at the $7.5 billion requested for FY 2001. The DSB noted that DoD S&T budget requests for FY 1997 through 2001 did not keep up with inflation and dropped from 3 percent to less than 2.6 percent of the total DoD budget request. The DSB believed that DoD must pursue a strong, forward-looking S&T program and not depend on civil sector research for all DoD needs. The DSB recommended that, to address civil service system problems, the DoD use the private sector, universities, and industry to provide the majority of personnel for DoD and service laboratories. The DSB recommended that the DoD place greater emphasis on innovative technology initiatives leading to entirely new military capabilities and that DoD and the services should consolidate and modernize their research and development (R&D) facilities (DSB, 2000).

The second recent DSB report that was particularly pertinent to Air Force S&T program-wide issues was entitled *Defense Science and Technology,* and was published in May 2002 (DSB, 2002). The Under Secretary of Defense for Acquisition and Technology had asked the 2001 summer study task force that wrote this report to examine three areas: how DoD S&T investment should be spent, the level of investment in S&T, and how the military can realize the most value from S&T investment. In its response, the DSB task force made the following recommendations:

- Invest in new S&T initiatives in support of four transformational challenges: defending against biological warfare defense [sic], finding difficult targets, making timely and accurate decisions, and enabling high-risk operations. Expand and provide more focused management for ongoing related S&T programs.
- Maintain the level of S&T investment at 3 percent of the overall DoD budget as currently planned by the Department. Provide additional funds for new S&T priorities by reprioritizing current programs.
- Exploit commercial technology through expanded use of commercial products and processes; elimination of barriers for commercial firms to do business with the DoD; and new initiatives to forge relationships with commercial industry.
- Foster operational experimentation as an integral element of a new S&T enterprise through assigned experimental units and sustained senior attention.
- Establish a new technology transition process with wide use of spiral development, routine inclusion of independent red teams, and acceleration of the acquisition cycle. Vest responsibility for joint operational experimentation, ACTDs, and transition with the Director of Transformation.
- Enable development and acquisition of joint R&D by establishing points of clear responsibility in joint C4ISR and biological warfare defense.
- Restructure the DoD laboratories and rebuild the scientific and engineering workforce based on a major review of the function and workforce in each laboratory (DSB, 2002).

AIR FORCE SCIENTIFIC ADVISORY BOARD

Like the DSB does for DoD leaders, the Air Force Scientific Advisory Board (AF SAB) provides advice on S&T and other technical issues to Air Force leaders (see Box E-2). The SAB has conducted numerous studies and issued reports dealing with or involving the Air Force S&T program. The Air Force identified five recent SAB reports containing recommendations relevant

BOX E-2
Air Force Scientific Advisory Board

The Air Force Scientific Advisory Board (AF SAB) is a federal advisory committee organized under the Federal Advisory Committee Act (1972). The SAB provides a link between the Air Force and the nation's scientific community. The SAB promotes the exchange of the latest scientific and technical information that may enhance the accomplishment of the Air Force mission. In addition, it may consider management challenges that affect Air Force use of scientific knowledge and technological advances. The board's function is solely advisory; it provides findings and recommendations to the Air Force senior leadership—namely, the Secretary of the Air Force or the Chief of Staff of the Air Force.

The board reports to the Secretary and to the Chief of Staff of the Air Force. Logistical and administrative support for the SAB is provided by an Air Force headquarters secretariat led by an executive director. The principal military deputy to the assistant secretary of the Air Force for acquisition serves as the executive director. SAB reports are subject to approval by the assistant secretary and/or Secretary of the Air Force or the Under Secretary of the Air Force prior to release to the public.

SOURCE: See <http://www.sab.hq.af.mil> [August 20, 2002].

to this study (Schneider, 2002a). Several of these reports were focused on specific technology or mission areas. One recent SAB report, however, specifically focused on Air Force S&T program-wide issues.

In its *Report on Science and Technology and the Air Force Vision: Achieving a More Effective S&T Program,* the SAB (2001) addressed several concerns, including pressure on the Air Force top line budget, lack of an effective methodology for valuing and prioritizing S&T investments in warfighter terms, lack of visibility into the program, the extent to which external S&T sources (defense, industry, academia) offset the need for Air Force S&T investment, and efficiency of S&T program execution.

In its report, the SAB made several recommendations. They included the following:

- Summary recommendations for the Secretary of the Air Force (SECAF) and Chief of Staff of the Air Force (CSAF)
  —Set specific Critical Future Goals (CFGs) that provide a basis for key system/operational concepts and S&T planning.
  —Hold the Air Force Research Laboratory commander (AFRL/CC) accountable for formulating and executing an S&T plan that achieves the CFGs and other warfighter requirements.
  —Create a program element to reenergize development planning.
  —Direct increased emphasis on the accession, retention, and development of S&E officers.

- Summary recommendation for the Air Force Service Acquisition Executive (AF SAE)
  —Hold AFRL/CC accountable for executing the S&T plans to provide the needed technical performance on the agreed schedule for the agreed cost.

- Summary recommendations for the Air Force Materiel Command commander (AFMC/CC)
  —Lead implementation of revitalized development planning, integrating across product centers, and use to establish priorities for the S&T plan.
  —Advocate the S&T program and budget as represented in the S&T plan into the new Air Force Resource Allocation Process (AF RAP).
  —Chair Applied Technology Council (ATC) meetings when competing concepts involve multiple product centers.
  —Play an increased role in S&E officer development and retention.

- Summary recommendations for AFRL/CC
  —Use trade studies from development planning to focus and prioritize S&T investments to achieve CFGs and meet other warfighter requirements.
  —Characterize the value of the entire S&T program in warfighter terms and present the characterization to Air Force leadership annually.
  —Hold program managers accountable for cost, schedule, and performance for each of the CFGs and other key projects.
  —Increase emphasis on tracking and acquiring commercial technology—incentivize "buy before make" behavior (SAB, 2001).

Although in its terms of reference for the study cited above, the SAB was requested to recommend a top line for Air Force S&T (an investment level for total Air Force S&T), none of the recommendations above calls for a specific top line. Instead, the SAB concluded that there was no unassailable way to establish a top line. The SAB noted the previous DSB report, which recommended that DoD invest 3 percent of DoD total obligational authority (TOA) in S&T. The DSB had made its recommendation after considering average R&D investment levels (as a percentage of annual revenues) of several industrial sectors. The SAB, however, did not find the industrial sectors that the DSB had examined to be easily associated with the Air Force S&T investment level. Instead of recommending that the Air Force S&T top line be based on some percentage of Air Force TOA, similar to what the DSB had recommended for DoD S&T, the SAB believed that the Air Force S&T top line should be determined on the basis of the cost of the S&T program needed to satisfy the Air Force's critical future capabilities (CFCs) and critical future goals (CFGs). The SAB said that the resulting S&T percentage of Air Force TOA could then be compared to historical averages (1.8 to 2.2 percent) for reasonableness, stating, "if the S&T investment is out of this range, the rationale should be explainable based on special circumstances or needs" (SAB, 2001).

AIR FORCE ASSOCIATION

The Air Force Association (AFA) is an independent organization that advocates on behalf of the Air Force and Air Force issues (see Box E-3). In January 2000, the S&T committee of the AFA released a special report (AFA, 2000) expressing the committee's concerns about the Air Force S&T program. Included were its concern about the decline in Air Force S&T funding since the end of the Cold War in constant dollars and as a percentage of Air Force TOA, concern about the lack of Air Force research and development (R&D) advocacy and institutional planning, and concern about the diminishing number of highly qualified Air Force acquisition officers.

To address those concerns, the AFA S&T committee made several recommendations: that the Air Force create a high-level annual review of Air Force R&D programs; that the Air Force reverse the decline in S&T funding and invest in a stable, robust, balanced R&D base not necessarily tied to emerging weapon systems programs and that it include long-term S&T investment; and that the Air Force protect technology base funding from arbitrary budget cuts. Also recommended

BOX E-3
Air Force Association

The Air Force Association (AFA) is an independent, nonprofit, civilian organization promoting public understanding of aerospace power and the pivotal role it plays in the security of the nation. AFA publishes *Air Force Magazine,* sponsors national symposia, and disseminates information through outreach programs of its affiliate, the Aerospace Education Foundation.

The AFA has over 142,000 members and more than 200 chapters, including Air Force enlisted, officers, civilians, Reserve and Guard, veterans, cadets, Civil Air Patrol, and others. Its national headquarters is located in Arlington, Virginia. Although its membership includes many retired and active-duty members of the Air Force, the AFA is independent of the Air Force. Its position on issues may or may not agree with the official positions of current Air Force leaders or representatives.

SOURCE: See <http://www.afa.org> [August 20, 2002].

were that the Air Force tolerate failure as an integral part of the technology development process, strengthen institutionally the role of technology advocacy within the Air Force, and, in the AFRL strategic plan, balance Major Command (MAJCOM) interests and promising technology not directly tied to current weapon systems (AFA, 2000).

OTHER RECENT STUDIES

In addition to the studies and reports described above, three other recent reports have addressed issues and concerns particularly pertinent to the Air Force S&T program. These are described below.

The first was the National Research Council report *Review of the U.S. Department of Defense Air, Space, and Supporting Information Systems Science and Technology Program* (NRC, 2001a). This was the study and report required by Congress in Section 214 of FY 1999 National Defense Authorization Act (P.L. 105-262, described earlier). Congress was concerned about the adequacy of the DoD air, space, and supporting information systems technology base; the declining DoD S&T investments in these areas; and reductions in the number of S&T personnel. The focus of concern was the Air Force S&T program.

The NRC study committee presented the following conclusions in its 2001 report (NRC, 2001a, pp. 5-7):

- Air Force investments in air, space, and supporting information systems S&T were too low to meet the challenges that the Air Force faced.
- Authoritative, S&T-focused and -dedicated representation and advocacy were needed at the corporate policy- and decision-making level of the Air Force.
- Reductions in the Air Force S&T workforce and rules governing S&T worker hiring, firing, and management had helped undermine the Air Force S&T program.
- Personnel management rules threatened the quality of the Air Force S&T program.
- The talents of the Air Force's technically educated officer corps were not being fully exploited, the benefits of locating uniformed personnel close to S&T performers were being lost, and the number of Air Force officers understanding the importance of S&T was decreasing.

To address these problems, the NRC made the following six overarching recommendations (NRC, 2001a, pp 5-7):

1. The Air Force should increase its S&T investment $1^1/_2$ to 2 times the FY 2001 level.
2. The Air Force should take actions to further strengthen S&T representation and advocacy at Air Force corporate policy- and decision-making levels.
3. The Air Force should take maximum advantage of the flexibility offered by section 246 of FY 1999 national defense authorization act to manage its S&T workforce.
4. The Air Force should improve development and use of its military S&T workforce.
5. The Air Force should implement remedial actions proposed by previous reports.
6. The Air Force should work with Congress to modify Civil Service rules.

The second report referred to above was also published by the NRC in 2001; it is entitled *Review of the Future of the U.S. Aerospace Infrastructure and Aerospace Disciplines to Meet the Needs of the Air Force and Department of Defense* (NRC, 2001b). This study and report were requested by the Principal Deputy to the Assistant Secretary of the Air Force for Acquisition to address the Air Force's concerns about the continued ability of the aerospace industry to produce cutting-edge products and attract highly skilled technical people, the Air Force's ability to attract similar personnel, the adequacy of the level of R&D and S&T funding provided by the government and the commercial sector, the future of research and test facilities, and maintenance of U.S. superiority and leadership in aerospace.

This NRC committee made several recommendations, including the following (NRC, 2001b):

- The Air Force should establish a deputy chief of staff position within Air Force headquarters with primary responsibility for oversight of all Air Force scientific and technical resources.
- The Air Force should regularly assess the quality and quantity of Air Force technical personnel; use assessments to define types and numbers of personnel necessary; and use as basis for making policy decisions.
- The Air Force should balance current expenditures and investments in future technologies and insulate latter from vagaries of near-term fiscal pressures.
- The Air Force should take into consideration the effects of the Air Force budget and management policies on industry.
- The Air Force should reduce acquisition cycle times.
- The Air Force should reform Civil Service rules for scientific and technical personnel.
- The Air Force should establish long-term, stable partnerships with supporting universities and faculty.
- The Air Force should communicate and broadly distribute a strong, positive message describing Air Force technical plans and opportunities.

Lastly, the third recent study that addressed issues and concerns pertinent to the Air Force S&T program was entitled "Science and Technology Community in Crisis," sponsored by the Director Defense Research and Engineering (DDR&E) (Lackie, 2002). During the fall of 2001 and winter of 2002, this study was conducted under the auspices of the Naval Research and Advisory Committee (NRAC); however, the study panel included members of each of the three military departments' scientific advisory boards, and the study included on-site visits to each of the three service corporate research laboratories. The study panel was asked to examine the role of the laboratories in the 21st century; the characteristics of a world-class S&T laboratory; recommendations from past studies of DoD laboratories, including the benefits derived from those implemented, the continuing value of those not implemented, and recommendations for gaining approval in the future; recent legislative initiatives; and near- and long-term strategies for laboratory excellence. The terms of reference for this study recognized that this area had been studied many times before, so it focused on reviewing the conclusions of past studies and updating their recommendations to accommodate 21st-century conditions and challenges.

The study panel (Lackie, 2002) found that the laboratories continued to be essential and critical, that the primary characteristic exhibited and needed by world-class laboratories was possession of the highest-quality scientists and engineers, that there had been many past studies that were mostly well done but that few of their recommendations had been implemented, that Congress had recognized the problems and tried to help, and that the fundamental strategy needed for near- and far-term laboratory excellence was to act and sustain commitment, now and in the future.

The panel made three summary recommendations (Lackie, 2002): (1) DDR&E should obtain the Secretary of Defense's and the service secretaries' commitment to the need, importance, and value of the corporate research laboratories by demonstrating continuing support for the implementation of the following two recommendations; (2) the Secretary of Defense should use the authority granted by Section 1114 of the FY 2001 National Defense Authorization Act (P.L. 106-398) and any other necessary authorities granted by Congress, to establish a separate personnel system for scientists and engineers in the three corporate research laboratories; and (3) DDR&E should develop and propose additional legislation to enable the services to experiment with alternative governance structures that would address additional laboratory issues such as salary caps, facility and equipment renewal, and laboratory director authority.

Appendix F

Biennial Iterative Review of the 6.2 and 6.3 Programs at the Margin

The following is an example of an approach that the Air Force could use for biennial review of 6.2 and 6.3 programs at the margin. This approach, illustrated in Figure F-1, is modeled on a process applied successfully in planning S&T work in the defense industry.

As shown in Figure F-1, two iterative reviews would be conducted in each biennium—industry experience has shown that two reviews are needed in each cycle—in preparation for the biennial Program Objectives Memorandum (POM). (The review process could, of course, be applied on the alternate years if a sufficient change in the Air Force Research Laboratory (AFRL) POM indicates the need.) In preparation for the first iteration, AFRL could prepare for the POM much as it currently does, including the Scientific Advisory Board's (SAB's) quality review. AFRL could nominate the program elements (PEs)/projects/tasks to be considered at the margin, and the directors of the AFRL technology directorate could champion or advocate their projects/tasks as they come under consideration in the review.

In the first iteration, the review could focus on projects or tasks that AFRL ranks within about ±20 percent of the annual planning and programming guidance (APPG) funding line by reprioritizing "gold watches" and projects/tasks of high interest and eliminating those of little interest, with the aim of reducing the focus for the second iteration to within about ±10 percent of the APPG funding line. Action items could also be assigned to support the second iteration.

In the second iteration, the review could refine the programs at the margin to form the recommended S&T program and the most compelling unfunded requirements in preparation for a review of the 6.3 advanced technology demonstrations (ATDs) by the Applied Technology Councils (ATCs) and for submission of the AFRL POM to the Air Force Materiel Command. In the second iteration, the focus could be on the opportunities pursued or lost through funding or not funding programs at the margin.

Those shown in the following list are the individuals who could conduct the iterative review:

- *Co-chairs:* Director, Air Force Strategic Planning, and AFRL Commander
- *Members:* Directors of Requirements for ACC, AMC, AFSPC, AFSOC, and AFMC
- *Observer:* SAF/AQRT
- *Advisors:* Directors of Development (Capability) Planning for AF Product and Logistic Centers and members of the Air Force Scientific Advisory Board (SAB)

There are two reasons for a key role for the director of Air Force Strategic Planning. First, he or she can contribute detailed knowledge of the Air Force strategic plan and the associated thinking of the Air Force senior leadership, which is essential if the S&T program is to be linked to the Air Force's vision for the future. Second, the detailed view of the opportunities offered by the S&T program provided by the reviewers' deliberations should be valuable in the continuing development of the Air Force vision and strategic plan. The AFRL commander can serve as a champion of both technology push and the remaining "seed corn." The directors of requirements for the major commands can

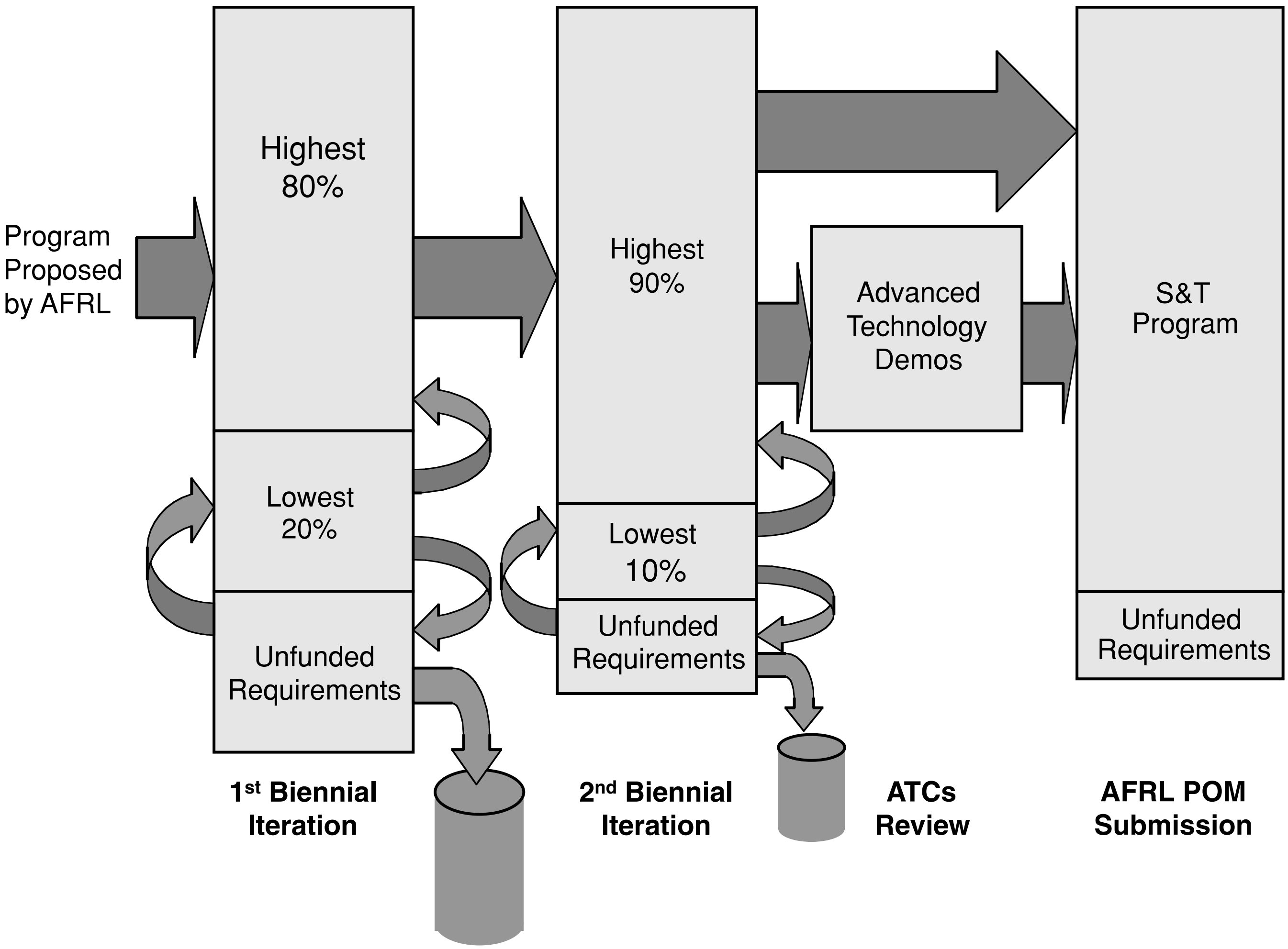

FIGURE F-1 Process for biennial iterative review of 6.2 and 6.3 programs at the margin.

provide operational pull. The directors of development planning can provide advice, since they are in unique positions to identify the technology needed by the current and anticipated acquisition programs. Members of the SAB who have become intimately familiar with the S&T program as a result of the SAB's quality review could offer a valuable "outsider's" perspective to the review.

After the first cycle, the Air Force could document the lessons learned and institutionalize the process.