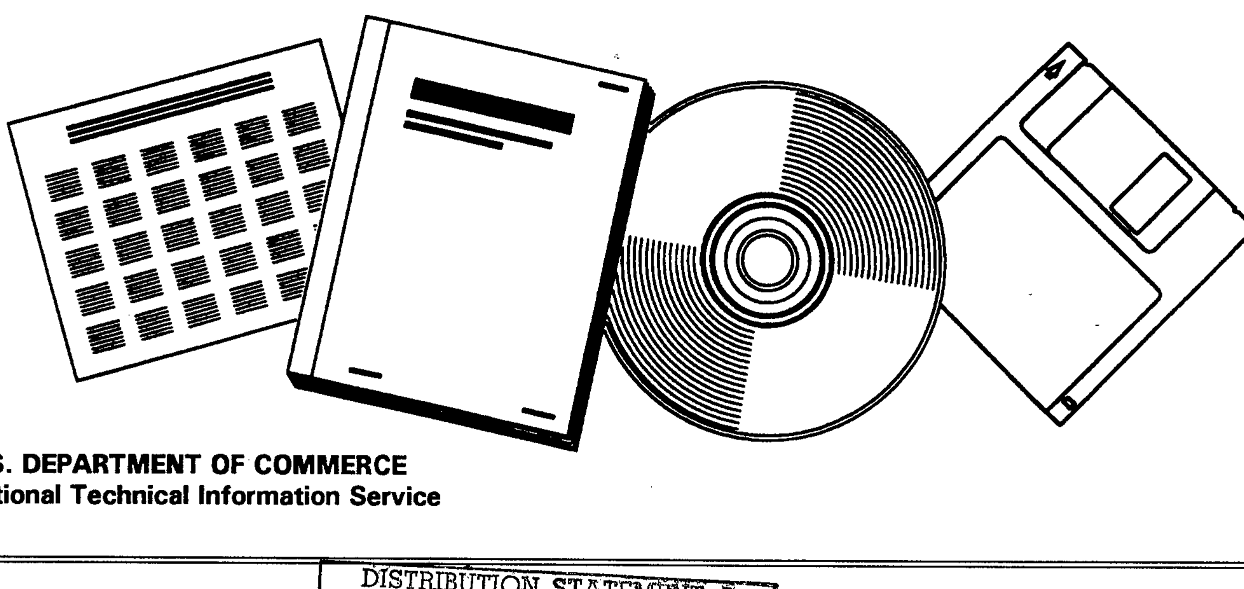
PB94-150844

MANAGING AIR FORCE BASIC RESEARCH

NATIONAL RESEARCH COUNCIL
WASHINGTON, DC

19970505 044

NOV 1993



U.S. DEPARTMENT OF COMMERCE
National Technical Information Service

50272-101

REPORT DOCUMENTATION PAGE	1. REPORT NO.	2.	3. PB94-150844

4. Title and Subtitle MANAGING AIR FORCE BASIC RESEARCH	5. Report Date Nov. 14, 1993 6.
7. Author(s) Committee on Air Force Research Management	8. Performing Organization Rept. No.
9. Performing Organization Name and Address National Research Council Commission on Engineering and Technical Systems 2101 Constitution Ave., N.W. Washington, DC 20418	10. Project/Task/Work Unit No. 11. Contract(C) or Grant(G) No. (C) (G) F49620-90-C-0012C
12. Sponsoring Organization Name and Address Air Force Materiel Command Wright-Patterson Air Force Base OHIO 45433	13. Type of Report & Period Covered Final 14.

15. Supplementary Notes

16. Abstract (Limit: 200 words)

The report's summary, reviews the major finding and recommendations of the National Research Council (NRC) Committee on Air Force Research Management. The committee was formed at the request of the Air Force Systems Command to assess the effectiveness of Air Force management of basic (6.1) research and to recommend any needed improvement. Subcommittee reports, on which the summary is based, are included as appendices.

The context of defense basic research has changed greatly in recent years. With the end of the Cold War this century's principal threat to national security has receded, and the threats, more localized but more unpredictable, have emerged. The nation also is facing strong budgetary pressures requiring that many national endeavors be rethought. Moreover, defense-related basic research itself has changed. It is now increasingly a global enterprise connected outside the U.S. services and beyond U.S. borders. For these and other reasons, many recent reports have focused on the problems and needs of defense research management (and defense management more generally). All these factors played a role in prompting Air Force interest in the issues of basic research management which are addressed in this report.

17. Document Analysis a. Descriptors

Air Force; basic research management; defense research

b. Identifiers/Open-Ended Terms

AFMC; AFOSR; AFSC; DOD

c. COSATI Field/Group Basic Research

18. Availability Statement	19. Security Class (This Report)	21. No. of Pages
Distribution is unlimited	Unclassified	94
	20. Security Class (This Page)	22. Price
	Unclassified	

(See ANSI-Z39.18) See Instructions on Reverse OPTIONAL FORM 272 (4-77) (Formerly NTIS-35) Department of Commerce

NRC NAS NAE IOM

PB94-150844

Managing Air Force Basic Research

PB94-150844

MANAGING AIR FORCE BASIC RESEARCH

COMMITTEE ON AIR FORCE RESEARCH MANAGEMENT
AIR FORCE STUDIES BOARD
COMMISSION ON ENGINEERING AND TECHNICAL SYSTEMS
NATIONAL RESEARCH COUNCIL

NATIONAL ACADEMY PRESS
Washington, D.C. 1993

NOTICE: The project that is the subject of this report was approved by the Governing Board of the National Research Council, whose members are drawn from the councils of the National Academy of Sciences, the National Academy of Engineering, and the Institute of Medicine. The members of the Committee responsible for the report were chosen for their special competence and with regard for appropriate balance.

This report has been reviewed by a group other than the authors according to procedures approved by a Report Review Committee consisting of members of the National Academy of Sciences, the National Academy of Engineering, and the Institute of Medicine. The National Academy of Sciences is a private, non-profit, self-perpetuating society of distinguished scholars engaged in scientific and engineering research, dedicated to the furtherance of science and technology and to their use for the general welfare. Upon the authority of the charter granted to it by the Congress in 1863, the Academy has a mandate that requires it to advise the federal government on scientific and technical matters. Dr. Bruce M. Alberts is president of the National Academy of Sciences.

The National Academy of Engineering was established in 1964, under the charter of the National Academy of Sciences, as a parallel organization of outstanding engineers. It is autonomous in its administration and in the selection of its members, sharing with the National Academy of Sciences the responsibility for advising the federal government. The National Academy of Engineering also sponsors engineering programs aimed at meeting national needs, encourages education and research, and recognizes the superior achievements of engineers. Dr. Robert M. White is president of the National Academy of Engineering.

The Institute of Medicine was established in 1970 by the National Academy of Sciences to secure the services of eminent members of appropriate professions in the examination of policy matters pertaining to the health of the public. The Institute acts under the responsibility given to the National Academy of Sciences by its congressional charter to be an advisor to the federal government and, upon its own initiative, to identify issues of medical care, research, and education. Dr. Kenneth I. Shine is the president of the Institute of Medicine.

The National Research Council was organized by the National Academy of Sciences in 1916 to associate the broad community of science and technology with the Academy's purposes of furthering knowledge and advising the federal government. Functioning in accordance with general policies determined by the Academy, the Council has become the principal operating agency of both the National Academy of Sciences and the National Academy of Engineering in providing services to the government, the public, and the scientific and engineering communities. The Council is administered jointly by both Academies and the Institute of Medicine. Dr. Bruce M. Alberts and Dr. Robert M. White are chairman and vice chairman, respectively, of the National Research Council.

This is a report of work supported by Grant No. F49620-90-C-0012C from the Air Force to the National Academy of Sciences/National Research Council.

A limited number of copies are available without charge from:
Air Force Studies Board, HA-258, National Research Council
2101 Constitution Avenue, N.W., Washington, D.C. 20418, (202) 334-3531

Printed in the United States of America

COMMITTEE ON AIR FORCE RESEARCH MANAGEMENT

STANLEY I. WEISS, (*Chairman*), Massachusetts Institute of Technology, Cambridge
VADM ALBERT J. BACIOCCO, USN (Ret.), Baciocco Group, Falls Church, Virginia
GILBERT F. DECKER, ACUREX Corporation, Mountain View, California
CHRISTOPHER C. GREEN, General Motors Research Laboratories, Warren, Michigan
ERICH P. IPPEN, Massachusetts Institute of Technology, Cambridge
JACK L. KERREBROCK, Massachusetts Institute of Technology, Cambridge
WILLIAM L. LEHMANN, University of New Mexico, Albuquerque
GEORGE H. MILEY, University of Illinois, Urbana-Champaign
PAUL F. PARKS, Auburn University, Auburn, Alabama
C. KUMAR PATEL, AT&T Bell Laboratories, Murray Hill, New Jersey
ELIZABETH J. ROCK, Wellesley College, Wellesley, Massachusetts
DANIEL P. SCHRAGE, Georgia Institute of Technology, Atlanta
CHARLES A. ZRAKET, MITRE Corporation, Bedford, Massachusetts

Liaisons

LT COL LARRY DAVIS, Air Force Office of Scientific Research, Washington, D.C.
COL ROBERT COCHOY, Wright-Patterson AFB, Ohio

Staff

RICHARD E. ENTLICH, Director (until January 1, 1993)
BRUCE A. BRAUN, Director (from January 1, 1993)
JOSEPH A. BREEN, Study Director
ANN COVALT, Consulting Writer/Editor
PAUL D. HILL, Administrative Assistant
ALICIA E. CLARK, Senior Program Assistant (until April 1, 1993)
ALLISON P. KNIGHT, Project Assistant

AIR FORCE STUDIES BOARD

WILLIAM J. EVANS, *Chairman* (1993) U.S. Air Force (Retired), Boothbay Harbor, Maine
JOSEPH F. SHEA, *Chairman* (1992) Massachusetts Institute of Technology, Cambridge
WALTER R. BEAM, Consultant, Alexandria, Virginia
JOSEPHINE D. DAVIS, City University of New York, Jamaica, New York
GILBERT F. DECKER, ACUREX Corporation, Mountain View, California
STEVEN D. DORFMAN, Hughes Aircraft Company, Los Angeles, California
CRAIG L. FISCHER, Diametrix Incorporated, Indio, California
WESLEY L. HARRIS, University of Tennessee Space Institute, Tullahoma, New York
JAMES E. HUBBARD, Jr., Charles Stark Draper Laboratory, Bedford, Massachusetts
WALTER B. LaBERGE, Consultant, Mission Viejo, California
JAMES W. MAR, Massachusetts Institute of Technology (Retired), Cambridge
GEORGE H. MILEY, University of Illinois, Urbana
HYLA S. NAPADENSKY, Napadensky Energetics, Evanston, Illinois
LAWRENCE R. RABINER, AT&T Bell Laboratories, Murray Hill, New Jersey

Staff

BRUCE A. BRAUN, Director from Jan 1993
RICHARD E. ENTLICH, Director from Nov 1990 to Dec 1992
JOSEPH A. BREEN, Study Director
MARY E. PECHACEK, Administrative Associate, 1992
PHILIP J. WALSH, Administrative Assistant, 1992
WILLIAM E. CAMPBELL, Administrative Assistant, 1993
PAUL D. HILL, Administrative Assistant, 1993
ALICIA E. CLARK, Senior Project Assistant, 1993

Contents

Illustrations

Figures

Table

Acronyms

ACISID	Advanced Computational & Information Sciences Directorate (Army)
AFAE	Air Force Acquisition Executive
AFB	Air Force base
AFCESA/RA	Air Force Civil Engineering Support Agency/Research and Acquisition (disbanded through reorganization, with one successor in the Armstrong Laboratory Environics Directorate, AL/EQ)
AFLC	Air Force Logistics Command
AFMC	Air Force Materiel Command
AFOSR	Air Force Office of Scientific Research
AFSC	Air Force Systems Command
AMC	Army Materiel Command
AO	Announcement of opportunity
ARDEC	Armaments Research, Development, and Engineering Center (Army)
ARI	Army Research Institute
ARIEM	Army Research Institute of Environmental Medicine (Army)
ARL	Army Research Laboratory
ARO	Army Research Office
ARTs	Aerospace Research and Technology committees (NASA advisory committees)
ASA(RDA)	Assistant Secretary of the Army (Research, Development and Acquisition)
ASBREM	Armed Services Biomedical Research, Evaluation and Management
ASIP	Aircraft Structural Integrity Program (Air Force)
ASL	Atmospheric Sciences Laboratory (Army)
ASTAC	Aeronautical Systems and Technology Advisory Committee (NASA)
AVRDEC	Aviation Research, Development, and Engineering Center (Army)
BED	Battlefield Environment Directorate (Army)

BES	Office of Basic Energy Sciences (DOE)
BRDEC	Belvoir Research, Development, and Engineering Center (Army)
BRDL	Biomedical Research and Development Laboratory (Army)
BRL	Ballistics Research Laboratory (Army)
CERDEC	Communications-Electronics Research, Development, and Engineering Center (Army)
CERL	Civil Engineering Research Laboratory (Army)
CNR	Chief of Naval Research
CRREL	Cold Regions Research and Engineering Laboratory (Army)
CSA	Chief of Staff of the Army
DA	Department of the Army
DARPA	Defense Advanced Research Projects Agency
DCSPER	Deputy Chief of Staff for Personnel
DDR&E	Director of Defense Research and Engineering
DOD	U.S. Department of Defense
DOE	U.S. Department of Energy
DRS	Defense Research Sciences (program element 6.1102F in the DOD budget, which supports most Air Force 6.1 research)
DSB	Defense Science Board
DT&E	Development, Test and Evaluation
EPSID	Electronics & Power Sources Directorate (Army)
ERDEC	Edgewood Research, Development, and Engineering Center (Army)
ETDL	Electronic Technology and Devices Laboratory (Army)
FAA	Federal Aviation Administration
FAR	Federal Acquisitions Regulations
GOCO	Government-owned, contractor-operated
HDL	Harry Diamond Laboratories (Army)
HEL	Human Engineering Laboratory (Army)
HQ	Headquarters
HRED	Human Research & Engineering Directorate (Army)
IDR	Institute of Dental Research (Army)
ILIR	In-House Laboratory Independent Research
IR&D	Independent Research and Development
ISC	Information Systems Command (Army)
JDL	Joint Directors of Laboratories
LABCOM	Laboratory Command (Army)
LAIR	Letterman Army Institute of Research
MATD	Materials Directorate (Army)
MRDC	Medical Research and Development Command (Army)

MRDEC	Missile Research, Development, and Engineering Center (Army)
MTL	Materials Technology Laboratory (Army)
NASA	National Aeronautics and Space Administration
NOARL	Naval Oceanographic and Atmospheric Research Laboratory
NRC	National Research Council
NRDEC	Natick Research, Development, and Engineering Center (Army)
NRL	Naval Research Laboratory
NSF	National Science Foundation
OER	Office of Energy Research (DOE)
ONR	Office of Naval Research
OSD	Office of the Secretary of Defense
PI	Principal investigator
R&D	Research and Development
RDEC	Research, Development, and Engineering Center (Army)
RDT&E	Research, Development, Test, and Evaluation
S&T	Science and technology
S3ID	Sensors, Signatures, Signal & Information Processing Directorate (Army)
SAB	Air Force Scientific Advisory Board
SAF/AQ	Assistant Secretary of the Air Force for Acquisition
SFRP	Summer Faculty Research Program
SLAD	Survivability/Lethality Analysis Directorate
SSDC	Space and Strategic Defense Command (Army)
SSTAC	Space Systems and Technology Advisory Committee (NASA)
T&E	Test and evaluation
TAP	Technology Area Plan
TAPSTEM	Training and Personnel Systems Science and Technology Evaluation and Management
TARDEC	Tank-Automotive Research, Development, and Engineering Center (Army)
TEC	Topographic Engineering Center (Army)
TEO	Technology Executive Officer
TSG	Threat Steering Group
URI	University Research Initiative
URRP	University Resident Research Program
USACE	U.S. Army Corps of Engineers
VAL	Vulnerability Assessment Laboratory (Army)
VPD	Vehicle Propulsion Directorate (Army)
VSD	Vehicle Structures Directorate (Army)
WES	Waterways Experiment Station (Army)

WRAIR	Walter Reed Army Institute of Research
WSMR	White Sands Missile Range (Army)
WTD	Weapons Technology Directorate

Summary Report

This summary report reviews major findings and recommendations of the National Research Council (NRC) Committee on Air Force Research Management. The committee was formed under the NRC's Air Force Studies Board, at the request of Air Force Systems Command, in the spring of 1991.[1] The object of this study was to assess the effectiveness of Air Force management of basic (6.1) research and to recommend any needed improvements.

The context of defense basic research has changed greatly in recent years. With the end of the Cold War, the principal threat to national security of this century has receded, and other threats, more localized but more unpredictable, have emerged. The nation also is facing strong budgetary pressures, requiring that many national endeavors be rethought. Moreover, defense-related basic research itself has changed. It is now increasingly a global enterprise, conducted outside the U.S. services and beyond U.S. borders. For these and other reasons, many recent reports have focused on the problems and needs of defense research management (and defense management more generally). All these factors played a role in prompting the Air Force interest in the issues of basic research management addressed here.

These trends also underlie recent organizational changes in the services. All three services have been engaged in consolidating and realigning their laboratories and reorganizing their research-related processes. In the Air Force, the original study sponsor, Air Force Systems Command (AFSC), was combined with Air Force Logistics Command, to form the new Air Force Materiel Command (AFMC), as of July 1, 1992, to unite research and development and logistics with the goal of new efficiencies.[2] The Air Force

---

[1] Because this study relied on the use of three subcommittees in approaching its task, this summary report serves both as a consensus report (Appendixes A-C provide the three subcommittee reports) and as an executive summary.

[2] These areas had been united before, under Air Materiel Command (and its predecessor, Air Corps Materiel Division), but they were functionally divided during World War II, and broken out under separate organizations in 1950.

Office of Scientific Research (AFOSR), which is the Air Force organization directly responsible for most Air Force basic research (in particular, the Defense Research Sciences program),[3] was once an element of AFSC; it is now within AFMC.

Insofar as possible, the committee has attempted to develop its observations and recommendations with attention to all these developments in the environment for Air Force basic research management.

The original study charges to the committee are as follows:

1. Compare the level, management, and allocation procedures for the 6.1 resources of each of the three services.
2. Assess the role and interaction of AFSC [AFMC] laboratories with AFOSR in the conduct of 6.1 research.
3. Evaluate the quality of the research products of AFOSR and the products of 6.1 in-house research.
4. Assess the means and extent of technology transition by AFOSR and by performers of 6.1 research.
5. Determine the extent of coverage by AFOSR of technical areas that have strong research activity by industry.
6. Identify technical areas that need greater coverage and areas that receive more attention than the research value warrants.
7. Compare, to a reasonable degree, AFOSR research and that of other research organizations.
8. Recommend ways to improve Air Force research management.

In initial meetings of the committee, it became clear that the answers to these charges would overlap in critical ways, and that the fifth and sixth charges—concerning the leveraging of research, satisfaction of critical research needs, and avoidance of research redundancy—could be addressed within the scope of this study only through a focus on management processes. A focus on process also allowed the committee to offer its insight on valuable general methods, rather than simply scattered, specific observations about current Air Force programs.

To best respond to its charge from the AFSC Commander, the committee thus formed three working groups, with the following emphases:

- interactions between AFOSR and the Air Force laboratories (Subcommittee A);

---

[3] Defense Research Sciences is the program element 6.1102F in the Department of Defense budget, representing most U.S. defense basic research.

- comparison of research management practices at AFOSR and other DOD and Federal Agencies (Subcommittee B); and
- quality of AFOSR-sponsored research (Subcommittee C).

While the main focus of Subcommittee A's study was the second charge, of Subcommittee B's the seventh, and of Subcommittee C's the third, all three subcommittees also considered all the remaining original charges, within their respective scopes. Much of the committee's information-gathering and deliberation took place within the three subcommittees, and all three subcommittees prepared written reports (Appendixes A-C), on which this summary report is based.

In the following review of findings and recommendations (organized by the original list of charges above), the views presented represent the consensus of the full committee.

In carrying out its study, the full committee or its subcommittees were briefed by the AFSC Director of Science and Technology, the AFSC Chief Scientist, the AFOSR Director, and senior managers and representatives of AFOSR, the Air Force laboratories, Army Research Organization, Office of Naval Research, Office of the Secretary of Defense, Defense Advanced Research Projects Agency, Air Force Scientific Advisory Board, National Science Foundation, U.S. Department of Energy, and National Aeronautics and Space Administration (see Appendix D fora list of these meetings). Committee members also made site visits to all four of the Air Force's newly formed "super" laboratories: the Armstrong, Phillips, Rome, and Wright laboratories.

Based on the information provided, the committee reached the following major findings and recommendations, for each of the original study charges. The reader is encouraged to consult the subcommittee reports in the appendices, for background information and analyses provided by the working groups.

LEVEL, MANAGEMENT, AND ALLOCATION PROCEDURES FOR 6.1 RESOURCES OF THE THREE SERVICES

DOD funding for basic research has been reasonably stable in constant dollars over the past decade. Stability of funding is critical for basic research, because its important results are generally less predictable and seen over a longer term than in applied research. Briefers of the committee indicated that the Air Force is attempting to maintain the stability of its basic research funding, even in the face of likely severe budget cuts over the next several years. This goal of funding stability is both desirable and practical, if the benefits of basic research are to be achieved.

According to information provided by DOD and the services' offices of research, Army 6.1 funding during fiscal year 1992 is approximately $197 million, Navy 6.1 funding $422 million, and Air Force 6.1 funding $203 million (see Appendix B, Figure B-4). These values represent 3.6 percent of the Army's total Research, Development, Test and Evaluation (RDT&E) funding, 4.2 percent of the Navy's; and 1.5 percent of the Air Force's (Figure B-5). Thus, the Air Force appears to commit a significantly smaller percentage of its total RDT&E funds to basic research than either of the other two services. The reasons for this discrepancy (and whether or not the ratios reflect realities) were not made clear, and the committee was unable to investigate this complex subject in satisfactory depth. The Air Force should consider whether further study of this issue is in order.

With the formation of AFMC, AFOSR has been placed within a much larger, more diverse organization. While some of the likely benefits of the merger are clear, the committee and other experts are concerned that, under the new organization, AFOSR may be too far removed from senior leadership, and thus basic research may be too far removed from planning and policy. Geopolitical and budgetary trends have changed the defense environment, but basic research remains as critical to achieving the Air Force mission as ever—it may even be more critical today, given the worldwide diffusion of high technology and new competition in research. Such observations raise the concern that basic research may not be given adequate emphasis within the new Air Force structure.

The services distribute their basic research funds through different organizational arrangements. The Army Research Office manages only the Army's extramural programs and its Centers of Excellence, that is, primarily university research, representing about one-third of the Army's basic research budget. The Office of Naval Research manages all Navy 6.1 funding. AFOSR also manages all Air Force 6.1 funds, except for In-House Laboratory Independent Research (ILIR) funds. There are advantages and disadvantages of these different practices, but no information provided to the committee suggested that Air Force practice should be changed. That is, the committee saw no evidence to question AFOSR's designation as the "single manager" of the Defense Research Sciences program.

Current AFOSR guidance suggests that about one-third of its Defense Research Sciences program funding should go to intramural research.[4] In-house basic research programs are essential, for mission-specific work, and

[4] "Guiding Principles for the Intramural Basic Research Program Sponsored by AFOSR" (see Appendix A, Attachment I, of this report).

perhaps more critically, to absorb the advances of the outside research community. Precisely because of the extensive expertise in the outside research community, Air Force support of extramural basic research is at least equally vital. Moreover, extramural research offers special benefits beyond connection with the outside research community and the opportunity to shape its interests. Air Force extramural research is highly leveraged, in funds, equipment, and intellectual resources; it also prepares the Air Force's future science and engineering work force, notably through the extensive involvement of graduate students in university research laboratories. While current budgetary trends may increase pressures within the Air Force to allocate a greater percentage of basic research dollars in house, the above considerations as a whole suggest that this would not be a prudent policy shift. (Once the unique contributions of intra- and extramural programs have been factored into allocation decisions, the only criteria the Air Force should use in its funding decisions are research relevance, quality, and productivity.)

Recommendations

1. The Air Force should maintain its 6.1 funding at no less than the current level, adjusted for inflation (and should perhaps consider devoting a greater percentage of RDT&E funding to basic research).
2. The importance of basic research to the Air Force's long-term warfighting capabilities must be recognized by its organizational structure. Given its current structure, the Air Force might best achieve this goal by ensuring that the Air Force Technology Executive Officer continues to be assigned his current level of responsibility and role, and, by virtue of training and background, continues to demonstrate strong knowledge and appreciation of basic research.
3. The Air Force should not make any policy change to shift basic research funding from extramural to in-house programs.

THE ROLE AND INTERACTION OF AFMC LABORATORIES WITH AFOSR IN THE CONDUCT OF 6.1 RESEARCH

A number of strategic planning processes shape the development of Air Force basic research programs: formal guidance received from the Assistant Secretary of the Air Force for Acquisition (SAF/AQ) and Director of Defense Research and Engineering, preparation of the Air Force Research Technology Area Plan (TAP), and Tri-Service S&T Reliance documents along with five complementary cross-cutting interlaboratory investment plans.

However, in the committee's view, none of these processes, individually or together, provides an adequate, integrated strategic plan for basic research that is oriented to meeting Air Force mission requirements.

Good mission-specific planning—which receives high-level attention—will be increasingly vital in an era of tight budgets. For example, a clear, directed plan of basic research will be needed to ensure the effectiveness and survivability of aircraft that must remain in operation for many years. These and other critical Air Force needs must be met, beginning with strategic planning. The committee saw laudable efforts in this direction on the part of AFOSR, which has emphasized research in a number of these particularly critical areas.

Mission-oriented planning should reflect the judgment of AFOSR, the laboratories, Air Logistics Centers, operational commands, and representatives of the larger R&D community. (One approach that has been applied to technology planning, the "Strategy to Task" approach, in which operators and researchers are involved in an active exchange of ideas, may also be of value in planning basic research.)

Strategic research planning in the new environment will require an increased focus on Air Force mission needs, but it should be emphasized that this focus should not lead to using 6.1 funds for applied research. Basic research can be more oriented to mission needs and still be fundamental science (e.g., basic science relating to corrosion). Moreover, to achieve the revolutionary advances of the future, some basic research must be strictly science-driven, pursued without concern for application.

The formulation of specific research programs is now largely a top-down process. Although AFOSR management staff receive guidance from a number of sources, they are largely responsible for funding decisions, initiation and guidance of research, and program quality. They are assisted in program planning by several advisory bodies, such as the AFOSR Research Council, which represents the laboratories through the participation of their chief scientists, and the Air Force Scientific Advisory Board.

Nevertheless, while valuable, these arrangements do not sufficiently involve those beyond AFOSR staff in program planning. Program planning would benefit from the greater involvement of laboratory staff, because of their special knowledge of Air Force technical requirements and their ability to better facilitate the transition of research results when they are familiar with the research. Laboratory staff report they are dissatisfied with their current level of involvement in program planning. However, in involving laboratory staff in program planning, care should be taken to avoid conflicts of interest (because the laboratories compete with extramural programs for basic research funding from AFOSR) and to avoid the diffusion of leadership in program planning, which could lead to poor coordination of research or tolerance of weak components.

The greater involvement in program planning of external peers from both academia and industry could also be highly beneficial. Currently, AFOSR research managers vary greatly in the way they seek external views on program formulation and funding decisions. For some AFOSR areas, such as Life and Environmental Sciences and Chemical Sciences, external peer review of proposals is a formalized process. In other cases, the external review sought is simply ad hoc. The more casual approaches raise concerns. External perspective on Air Force research programs can be invaluable in keeping programs at the leading edge of research, leveraging the work of others, avoiding research redundancy, introducing appropriate multidisciplinary thrusts, and achieving the highest quality research programs in general.

At the same time, like laboratory input to program planning, external review can present its own problems, including burdens of time, expense, and administrative work, and the possible introduction of other kinds of biases (see Appendixes A and B for background discussion).

Considered together, the benefits and drawbacks of involving external peers in program formulation lead committee members to hold a range of views. Some believe that external proposal review should be formalized across AFOSR, others that program managers should be encouraged (e.g., through performance reviews) to pursue greater external review, but in their own ways. Yet others would argue for convening outside advisory groups to review program plans in specific discipline areas, or for annual AFOSR surveys of outside research. However, the committee as a whole agrees strongly that external input to program planning should be given greater emphasis, for all the reasons above.

The centralization of authority in Air Force basic research planning also increases the risk that good innovative research may go unfunded. If proposed research is not of direct interest to a program manager, support for that research is likely to be minimal. AFOSR has not always moved well into new areas of research, even when given the guidance to do so (e.g., at SAF/AQ's request several years ago that it develop stronger research in logistics). AFOSR should be pursuing strong programs of basic research in areas that bear on logistics and manufacturing as well (e.g., in corrosion, stress-cracking, tribology, artificial intelligence for monitoring systems, and nondestructive evaluation).

One traditional research management problem is balancing nearer- and longer-term goals. The committee heard reports both that proposed basic engineering research is sometimes dismissed as "too applied" and that pressures within the Air Force sometimes lead in-house labs to overemphasize near-term results in their basic research, in this case forcing the choice of projects properly called "applied." Policies and procedures can be designed to help avoid such problems. Ratings of "relevancy," for example, should be clearly distinguished from the idea of "promising near-term results." Such issues could be further considered through a regular seminar for program managers (other likely seminar topics would include techniques to manage both small research groups and large integrated teams, and case histories in transition; see Appendix A).

Recommendations

1. Especially in view of current pressures on defense budgets, strategic planning for basic research should take greater account explicitly of long-term Air Force mission goals. This planning should reflect the judgment of AFOSR, the laboratories, Air Logistics Centers, operational commands, and representatives of the larger R&D community.

2. A small portion of Air Force basic research funding should also be set aside to pursue especially innovative research, regardless of the applications it promises.

3. The practice of briefing the basic research strategic plan to senior Air Force leaders at AFMC and Air Force Headquarters is strongly endorsed, along with other measures that enhance high-level understanding of the potential roles of basic research in meeting Air Force mission requirements.

4. To improve the formulation of basic research programs, AFOSR should involve at more of a "partnership" level those beyond its own staff, both those in the laboratories and external experts. Carefully designed procedures will be needed for this enhanced involvement to be successfully achieved.

5. In improving program planning procedures, the Air Force should consider better ways to incorporate critical new areas of research, for example, by establishing an interdisciplinary team of program managers, augmented appropriately by outside experts, to evaluate proposed research in new and interdisciplinary areas.

6. Air Force research management should develop policies and procedures to help program managers avoid arbitrary decisions in determining the "basic" or "developmental" nature of proposed research. For example, the nature of "relevancy" ratings should be made clear. Additionally, a continuing education seminar for program managers could be established to address such management questions.

QUALITY OF THE RESEARCH PRODUCTS OF AFOSR AND OF 6.1 IN-HOUSE RESEARCH

AFOSR has recently improved its procedures to assess research quality. "Relevancy" reviews conducted at each of the Air Force laboratories during the fall permit the labs to evaluate the AFOSR basic research programs in general, with emphasis on their responsiveness to Air Force needs. "Quality" reviews are also held at the fall meetings, in which invited members of the Air Force Scientific Advisory Board and AFOSR scientific directors complete quality review forms. Two overall ratings, one for quality and one for relevance, are thus produced for each program.

These procedures represent a significant advance over previous methods; however, they still have shortcomings. Because of the many work units covered in the current reviews, the reviews can be only cursory. Attendance of external peer reviewers is also quite limited. The review of basic research programs is therefore largely internal, and in-depth review of program quality remains highly dependent on the individual program manager. While many AFOSR program managers are clearly very talented and capable, this dependence on so few experts for the review of research is a limiting management strategy in today's research environment. Research is now far more widely conducted than in the past, and embodies many more efforts and specialized fields than can be mastered by so few individuals.

The available evidence suggests that the Air Force has a sound program of basic research. Informal review of AFOSR projects led the committee to conclude that the quality of many is high. AFOSR has also recently instituted the Star Team Award, to recognize its leading Air Force laboratory research teams. These awards are based on well-specified criteria, and they should be a valuable tool in promoting high-caliber research.

At the same time, serious difficulties were encountered in attempting to assess the overall quality of AFOSR-sponsored research, whether intra- or extramural, or as a whole. No systematic quality metrics are maintained on Air Force basic research. Such quality metrics are admittedly difficult to specify. However, a number of established indicators, while imperfect, could provide some objective benchmarks of research quality. Their systematic application would be of help in assessing, improving, and justifying the value of Air Force research programs.

The committee therefore developed a list of such quality indicators of special interest to AFOSR (Appendix C). For research personnel, these objective quality metrics include fellowships in professional societies, memberships in national academies, and other forms of professional recognition, such as society prizes and awards. Additional useful metrics are total research personnel breakdown by degrees and disciplines, and average professional age (and age distribution by fields and degrees). To benchmark the quality of research results, useful metrics include publications in refereed journals, citations, and patent activity. The systematic and regular capture of all such data could be used to evaluate and improve the quality of the AFOSR researcher pool and the quality of AFOSR research results.

The collection of several additional kinds of information could also be of great value to AFOSR. Ultimately, the transition of research results is one of the most important criteria of research quality and relevancy from the standpoint of AFOSR. While much anecdotal information is available about the transition of Air Force-sponsored research, systematic information is not kept. For this reason, the Air Force's success in transition of research results cannot be well evaluated, and the management steps that might improve this transition are hard to identify. Similarly, information on project results (for both successful and unsuccessful projects) could help improve project management and justification throughout the R&D management chain. Project results are now documented in various ways, but there is no systematic capture, storage, and distribution of such information, although the committee saw indications that the AFOSR Director is instituting efforts in this direction.

The quality of Air Force basic research also depends necessarily on the quality of the science and engineering work force over the long term. This work force includes not only research personnel in Air Force laboratories, but also researchers in universities and industry who directly and indirectly support Air Force RDT&E. To secure the reliable delivery of technology over time, AFOSR has been active in ensuring that such long-term work force needs are met. AFOSR programs for postdoctoral and faculty exchange, and for science and engineering education, are all aimed at supporting and developing this larger Air Force work force.

The study subcommittee that reviewed these current Air Force programs concluded that they provide financial support for a substantial number of faculty and postgraduate and graduate students (Appendix C). AFOSR science and engineering education programs also appear well designed to meet their objectives. However, especially in this period of tightening defense budgets, the committee is concerned that critical funding support in these areas may be cut, while no quantitative assessment has been made of future Air Force scientific work force needs. A good assessment should take into account the leveraging and technology transfer opportunities these forms of support provide. Additionally, it should be noted that significant time is required to bring research personnel through the educational pipeline, and it would be wise for the Air Force to make conservative assessments in this light. (Such strategic planning must be based on incomplete facts, but the planning process forces a valuable discipline, yielding important insights; and plans will be amended both with this experience and the availability of more accurate information.)

Recommendations

1. To improve its oversight of research quality, AFOSR should randomly select projects representing some minimum percentage of its annual basic research outlay (at least 10 percent) and subject these projects to detailed external peer review. Such reviews would provide valuable quality information and help validate internal reviews.

2. AFOSR should conduct internal, in-depth reviews of one-third of its research projects each year, so that every research project with a life of three years or more is subjected to rigorous benchmarking.

3. An organized database should be created and maintained on objective quality metrics for AFOSR researchers, and should be used as a tool to improve the overall quality of the pool of researchers.

4. Organized databases should also be created and maintained on publications in refereed journals, citations, and patent activity, to help assess and improve the quality of research results (including, e.g., to judge the relative contributions of intra- and extramural programs).

5. AFOSR should institute a process to capture information on the scientific impact and transition of its research results, to measure the effectiveness of its programs, improve its portfolio, and justify its research programs. (For more detail, see the section that follows.)

6. A systematically organized knowledge base of lessons learned from research projects should be developed and maintained, for better management of research and better use of research results.

7. AFOSR should ensure that a good quantitative assessment is made of future Air Force science and engineering work force needs. This assessment should result in a strategic plan for the support and development of faculty and postdoctorate and graduate students. Until the plan is prepared, AFOSR should continue its current levels of funding for university faculty and science and engineering education programs.

8. All the quality metrics identified should be used as the basis of an AFOSR annual report, to describe the quality and effectiveness of its program. The ongoing application of such metrics will allow AFOSR to better manage its programs, target its funds, and justify the value of its work.

MEANS AND EXTENT OF TECHNOLOGY TRANSITION BY AFOSR AND PERFORMERS OF 6.1 RESEARCH

The notional "linear model" of defense R&D, in which successful 6.1 program results lead to exploratory development in 6.2 programs, and so on, does not always function smoothly. The Air Force has clearly recognized and addressed this problem. Among other measures, the new "relevancy" ratings of 6.1 programs by the Air Force laboratories are a valuable method to help ensure the ultimate transitioning of 6.1 results. AFOSR has also used 6.1 dollars on occasion to encourage transition, as for a recent research consortium on microwave tubes. In the past few years, AFOSR has also instituted a new S&T Coordinator program, in which selected program managers are designated to facilitate transition between discipline-oriented basic research and the multidisciplinary, technology-oriented efforts of the Air Force laboratories.

Still, these valuable steps are not enough to solve the problem. As discussed immediately above, there are no systematic data on the transition of AFOSR-sponsored research. Thus, no real evaluation of the success of this transition is possible, and improving transition without such information is far more difficult. Again, a systematic information base on transition could be of great help in assessing and managing the process. The recent establishment of an AFOSR historian should be one useful step toward developing such an information base.

Other straightforward methods might enhance transition and could be implemented even before a database is developed. They include the greater identification of potential users of 6.1 research by program managers; the regular distribution of all 6.1 research reports to all identified potential users (such distribution is currently quite variable); encouraging better communication between 6.1 researchers and potential users, for example, through special meetings of the two groups, which might be scheduled at current annual review meetings; and the study of case histories in transition, for example, in the recommended ongoing seminar for program managers. Such actions could build on the S&T Coordinator program, which has been active in a number of these areas.

Recommendations

1. AFOSR should explore the development of a systematic information base on the transition of its basic research results. The Commander of AFMC should develop goals and guidelines for this new process either through the AFMC Technology Executive Officer or through AFOSR.

2. Additional means of encouraging technology transition should be pursued: distributing 6.1 research reports more systematically, encouraging further meetings between researchers and potential users, and examining cases histories in transition for the lessons they offer.

EXTENT OF COVERAGE BY AFOSR OF TECHNICAL AREAS THAT HAVE STRONG INDUSTRY RESEARCH ACTIVITY

The committee addressed the identification of research redundancy by considering Air Force research management processes. With roughly 1,500 Air Force basic research tasks currently underway, identifying research redundancy is a daunting task, if approached from the top down; and it certainly cannot be done by one small group of experts.

Of greater interest to the Air Force is how to avoid unwarranted redundancy of its basic research tasks over the long run, rather than merely today. This goal can be best achieved, again, through well-designed review processes. These processes should ensure that the views of appropriate experts both within and outside the Air Force are obtained about the value of specific research tasks. Experts representing the specialized fields at issue can provide the best advice to help avoid research redundancy.

Recommendation

To avoid unwarranted redundancy of Air Force and industry basic research, the Air Force should strengthen its means of achieving appropriate, ongoing external review of its basic research projects and programs.[5]

TECHNICAL AREAS THAT NEED GREATER COVERAGE AND THOSE RECEIVING MORE ATTENTION THAN THE RESEARCH VALUE WARRANTS

The committee addressed research omissions, like research redundancy, as a management process issue, for the same reasons. A number of the actions recommended throughout the report could help identify research omissions as well as research redundancies and inappropriate research

[5] The Semiconductor Industry Association (SIA) is attempting to establish a framework to rationalize new industry/government technology investments. Examining this effort was beyond the scope of the present study; but the Air Force might benefit from SIA's experience.

emphases. Beyond the greater involvement of external peers in research review, the greater involvement of the laboratories and other relevant Air Force groups in strategic and program planning, as earlier discussed, would help greatly in focusing research on areas of greatest need and opportunity in the context of the Air Force mission.

Recommendation

To ensure the best basic research emphases, the Air Force should promote the greater involvement of laboratories and other appropriate Air Force groups (e.g., operational commands), as well as the outside research community, in strategic and program planning and research reviews.

AFOSR RESEARCH MANAGEMENT COMPARED TO RESEARCH MANAGEMENT IN OTHER ORGANIZATIONS

Research practices of both DOD and non-DOD agencies were compared to those of AFOSR. Several resulting observations have already been made (see discussion of the first charge above, on level, management, and allocation procedures for 6.1 resources).

The review of DOD agencies led to several additional observations. First, it is difficult to achieve highly qualified, stable technical leadership through the rotation of military officers. The committee also heard some reports that the Air Force fails to look on research management assignments as positive military career moves (though this view was not universal). At the same time, AFOSR reports no significant difference in the performance of its military and civilian research managers. Some experts also pointed out that military research managers provide a better perspective on users' needs.

The second issue raised in the review of other DOD agencies was the need for discretionary laboratory funds. Numerous published reports and comments made to the committee suggest that discretionary laboratory funds, including ILIR funds, are vital to the laboratories' flexibility and their resulting ability to pursue innovative work. The 1983 Federal Laboratory Review Panel suggested that 5 to 10 percent of a laboratory's funding should be discretionary, a value range with which this committee agrees. At the same time, visibility on such discretionary work must be afforded to the rest of the Air Force research community, in particular to AFOSR, to allow coordination and avoid redundancy.

Third, the recently implemented Tri-Service S&T Reliance program was briefly reviewed. This set of formal agreements and processes to consolidate and collocate selected 6.1, 6.2, and 6.3A S&T programs of the three services was implemented in late 1991, under the direction of the Joint Directors of Laboratories (JDL). Reliance is still too young to assess fully, but it clearly offers valuable opportunities for research effectiveness and efficiency across DOD over the longer term. In the committee's view, Reliance as a whole has gotten off to a variable start; initial reports do indicate that it is providing identifiable benefits in particular areas (see, e.g., *Report of the 1992 Defense Science Board Task Force on Microelectronics Research Facilities*), and such successes could provide the basis for Reliance's future development.

Research management lessons the committee gleaned from the practices of non-DOD agencies concern mainly two areas: the use of external review to assure program quality, and the necessity of ensuring good continuing technical training of research managers.

Representatives of the non-DOD agencies consulted all stressed the value of their external review processes. All these agencies—DOE, NASA, and NSF—involve external reviewers in different ways in their proposal and project reviews. All report that these reviews significantly enhance both the quality and credibility of their programs. These various review processes have different strengths and weaknesses, as detailed in Appendix B. Comparative analysis as well as other observations, then, suggest that the Air Force might benefit greatly from this experience and, building on its own review processes and needs, devise better external review processes to improve its research management.

A problem commonly reported by the non-DOD agencies is the risk of research managers' losing their technical skills because of administrative burdens. This was not reported to be a serious problem for AFOSR program managers, but it should be carefully avoided, especially insofar as Air Force research managers have very significant technical decision-making authority.

Recommendations

1. The Air Force should continue to emphasize recruitment of civilian research managers to ensure stable, highly qualified technical leadership. For the same reason, longer tours of duty should be considered for military research managers. Their career opportunities should be ensured. All program managers should have solid training and experience, including technical management training and 3 to 5 years of technical management experience.

2. Laboratory discretionary funding, including ILIR funding, is essential for innovative lab work and should be protected. At the same time, AFOSR should be given review responsibility for ILIR work, to help provide a

common standard for quality and to assist in the integrated planning of Air Force research, especially to avoid research redundancy.

3. The Air Force should continue to pursue opportunities for research efficiency, as through strong participation in such cooperative efforts as Tri-Service S&T Reliance. Future development of Reliance should build on its identified successes, and its effectiveness should continue to be assessed and ensured through appropriate cross-service studies.

4. Examination of the practices of non-DOD agencies indicates that the Air Force should incorporate more in-depth, external technical review in its management of basic research. Improved Air Force review practices should take into account not only this experience, but also current Air Force practices and involved groups. Care must be taken to ensure that external review groups have a clear vision of potential Air Force needs.

5. The experience of other federal agencies demonstrates that Air Force program managers must be given the workload, span of control, and professional opportunities to allow the continual renewal of their technical skills.

Appendix A: Interactions Between the Air Force Office of Scientific Research and the Air Force Laboratories

William L. Lehmann, *Chairman*
Jack L. Kerrebrock
George H. Miley
Elizabeth J. Rock

The main charge to the subcommittee was to assess the interactions of the Air Force Office of Scientific Research (AFOSR) and the Air Force laboratories in carrying out 6.1 research (specifically, the Defense Research Sciences program element 6.1102F), to suggest ways of improving Air Force basic research management. The subcommittee was also mindful of the study charges to assess the means and extent of technology transition, and to consider issues of research funding, redundancy, and leveraging.

Policies and procedures governing the interaction of Air Force laboratories with AFOSR were covered in briefings to the full committee by the Director of Science and Technology and Chief Scientist of Air Force Systems Command (AFSC), the Director of AFOSR, and the Chief Scientist of the Wright Laboratory, the Air Force's largest laboratory. The subcommittee also made site visits to the Rome, Wright, and Phillips laboratories and attended AFOSR research program reviews held at the Rome, Phillips, Wright, and Armstrong laboratories. In the course of these meetings and site visits, the subcommittee also benefited from discussions with AFOSR scientific directors and program managers and with senior laboratory scientists.

The environment in which defense research is conducted and managed has changed notably in recent years. There have been downward budgetary pressures and they will likely continue. The threat environment has changed dramatically. Sophisticated basic research conducted outside both the services and the nation has greatly increased.

Clearly, past Air Force-sponsored research has made important contributions to the service's present military capability. Developments in lasers have improved precision-guided munitions. Advanced weather models have led to better target acquisition systems and combat communications. Basic research in aerodynamics has improved the performance of jet engine compressors, revolutionizing fighter aircraft performance and range. Life sciences research has expanded the G-loading envelope in which pilots can operate. Moreover, in the past 25 years, 20 Air Force-sponsored U.S. researchers have won Nobel prizes.

Even in the face of such achievements, though, it is valid to ask whether current research management policies and procedures are optimal, especially given the new defense research environment.

In any restructuring, several overarching principles must provide the framework for AFOSR-laboratory interactions. Commitment to serving the ultimate customer, the operational Air Force, is essential, especially to facilitate the transition of basic research efforts into operational capabilities. General policy and doctrine must also strongly shape research management. For example, because technological superiority is critical to fulfillment of national policy, the Air Force must be an active member of the basic research community spanning Air Force laboratories, the defense industry, and universities. Its research programs must serve not only Air Force acquisition, but also Air Force logistics and operations.

In providing specific comments below, this subcommittee report first outlines the organizational structures, roles, policies, and procedures that are central to Air Force management of basic research. It then examines the issues raised over the course of this study for interactions between AFOSR and the laboratories, and offers conclusions about means of improving Air Force research management.

OVERVIEW OF ORGANIZATIONAL STRUCTURES, ROLES, POLICIES, AND PROCEDURES

A successful Air Force program of basic research requires appropriate organizational structures and well-defined roles, policies, and procedures.

Structure of the Defense Research and Development Program

The defense research and development program is based on a "linear model": Research (program 6.1) leads to Exploratory Development (6.2), which leads to Advanced Development (6.3), then in turn to Engineering Development (6.4), and, ultimately, to the acquisition of new weapon systems, which provide the basis for a new force structure (Figure A-1). This "linear" R&D model is notional, of course, idealizing the true R&D process; these stages in fact interact in varied ways, with feedback loops of many kinds.

Other defense budget programs encompass operations and support, including logistics and basing. Operations, logistics, and basing are also some of the defense analogues of end products and manufacturing processes in the

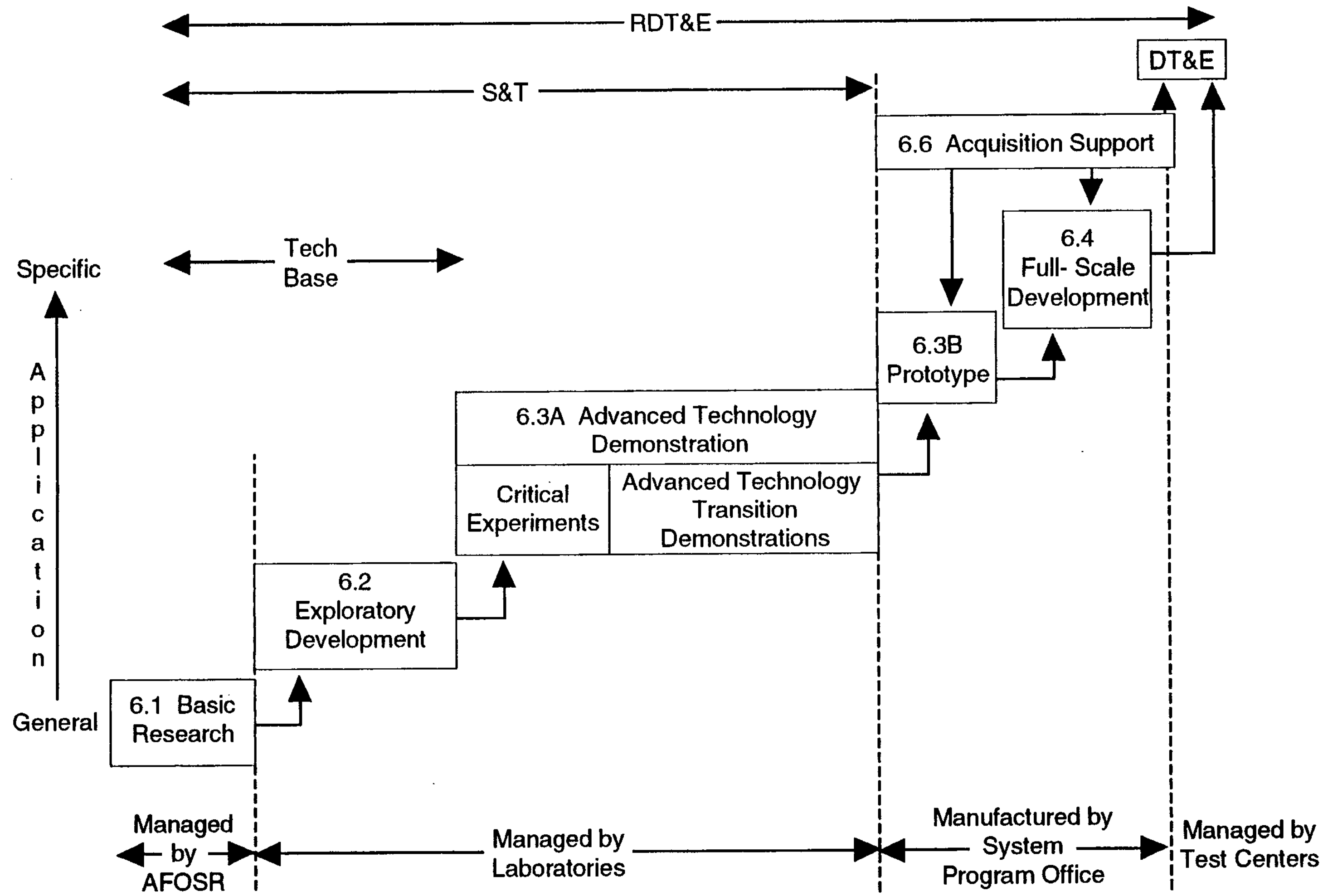


FIGURE A-1 The Air Force research and development process (adapted from material provided by Air Force Systems Command).

civil sector. Defense research is expected to contribute to operations and support, as well as to the acquisition of new systems, in the evolving defense program structure.

Air Force basic (6.1) research is the Defense Research Sciences program element (6.1102F) identified in the annual DOD budget. By guidance from the Director of Defense Research and Engineering (DDR&E), it is responsible for the following:

- discovery of new phenomena;
- visibility and exploitation of current and new scientific knowledge;
- filling gaps in the fundamental technical knowledge base in areas important to Air Force operations and support;
- transition of research results to further Air Force operational capability; and
- strengthening the research infrastructure in Air Force laboratories, including through the training of scientists and engineers in disciplines critical to Air Force needs.

Air Force Command Structure for Research and Development

Air Force Materiel Command (AFMC) is the Air Force organization responsible for the development and acquisition of new weapons systems and the support, maintenance, and modification of existing weapon systems.[1] AFMC elements important to research include AFOSR, which manages all Air Force basic research, both intra- and extramural, and the laboratories of the four Air Force product centers—Wright Laboratory of the Aeronautical Systems Center, Rome Laboratory of the Electronic Systems Center, Phillips Laboratory of the Space and Missile Systems Center, and Armstrong Laboratory of the Human Systems Center—which manage or conduct research at all stages of R&D through advanced development.

AFMC also has five Air Logistics Centers, with their engineering organizations, which apply existing and new technology for maintenance and modernization. New ideas and technology initiatives frequently come from these centers, are encouraged, and are exceptions to the "linear model." There are currently no formal ties between AFOSR and the Air Logistics Centers.

The AFMC Commander relies on a Director of Science and Technology and Director of Engineering for matters pertaining to research. The first is

[1] Over the course of this study, the original sponsor, Air Force Systems Command (AFSC) was merged with Air Force Logistics Command (AFLC) to form the new Air Force Materiel Command. The subcommittee has adapted its commentary accordingly.

responsible for the technology base (programs 6.1, 6.2, and part of 6.3). The second is responsible for engineering and support, and is a primary customer of the technology base.

Program Acquisition Structure

The acquisition of new weapon systems is managed by Acquisition Executives in each service, in the case of the Air Force, the Assistant Secretary of the Air Force for Acquisition (SAF/AQ). SAF/AQ is responsible for all Air Force 6.1, 6.2, 6.3, and 6.4 program elements.

SAF/AQ has designated the AFMC Director of Science and Technology as his Technology Executive Officer (TEO), with program responsibility for Air Force 6.1, 6.2, and certain 6.3 programs. The TEO briefs SAF/AQ on 6.1 research, which is represented by means of the Research Technology Area Plan (TAP), one of a dozen such plans.

Air Force Basic Research Program and Organization

AFOSR has "single manager responsibility" for the 6.1 Defense Research Sciences program (funded at about $203 million in fiscal year 1992) and the 6.1 University Research Initiative program (funded at about $22 million), reporting to the Commander AFMC through the Director of Science and Technology. The 6.1 In-House Laboratory Independent Research (ILIR) program ($8 million) is the responsibility of the lab directors.

The Air Force Defense Research Sciences program is broken down into 15 projects. Each project (funded at $5-40 million) is associated with a single research area, such as structural materials, atmospheric sciences, mathematical and computer sciences, or physics.

Each project area in turn is broken into individual grants, contracts, and laboratory tasks. There are some 1,400 grants and contracts (averaging about $100,000) with universities and industry, and some 100 intramural research tasks with Air Force laboratories (averaging $400,000). AFOSR guidance indicates that intramural investment should represent about one-third of the Air Force's Defense Research Sciences funding (see Attachment A-1, which provides an overview of roles and responsibilities relating to Air Force intramural basic research).

AFOSR's "single manager responsibility" encompasses the formulation of the Air Force Research program, coordination of intra- and extramural research, resource allocation, progress monitoring, review and evaluation of results, and transition to Air Force benefit. AFOSR also selects proposals and awards research grants and contracts to universities and industry.

The four Air Force laboratories are charged with building and maintaining the technology base appropriate to their parent centers: each laboratory conducts in-house work in Research (6.1), on the order of $10 million; carries out in-house and contractual efforts in Exploratory Development (6.2), on the order of $100 million; and formulates and manages contractual efforts in Advanced Development (6.3), on the order of $100 million. Individual laboratory manning is on the order of 1,500 to 2,500, plus on-site support contractors.

Each laboratory has a commander or director, assisted by a laboratory chief scientist, and from 5 to 10 directorates, each with its own associate chief scientist (associate chief scientists report to the chief scientists of their respective laboratories).

To formulate the Air Force Research program for the fiscal year, the AFOSR Director receives annual policy guidance and resource direction from the AFMC Director of Science and Technology, and is assisted in program planning by the five AFOSR scientific directors, a Research Council consisting of himself and the chief scientists of the four laboratories, and his staff. Together they monitor progress and review and evaluate results of the research projects, and report annually.

Each of the five AFOSR scientific directors has responsibility for one or more of the research projects. The scientific director is assisted in this by appropriate lab directorate chief scientists and 5 to 10 AFOSR program managers (there are a total of 40 some program managers overall). Each program manager selects from 20 to 40 proposals for contract or grant award.

In addition, the Air Logistics Center engineering groups, which assure the maintenance and quality of existing aircraft and missiles, also benefit from technical partnerships with Air Force laboratories and AFOSR.

AFOSR also has a small in-house research program at the Seiler Laboratory at the Air Force Academy and research liaison offices in Europe and Japan.

Additional roles, policies, and procedures relating to Air Force management of basic research are described under the discussion of issues below.

ISSUES

Based on briefings and site visits, the subcommittee identified a number of important issue areas. Each is discussed below, and conclusions are offered for the questions that arose concerning each area.

Air Force Funding of 6.1 Research

- *Is the current Air Force RDT&E investment in 6.1 research appropriate?*
- *Is the present division of 6.1 funding between intra- and extramural research appropriate?*

The fraction of Air Force RDT&E funding that goes to 6.1 research is only about half of the corresponding value for Army and Navy 6.1 research (see Appendix B, Figure B-5). No clear explanation for this discrepancy was presented to the subcommittee. Thus, whether the Air Force is investing appropriate resources in 6.1 research is an open question.

AFOSR 1992 "Guiding Principles" for the intramural basic research program (Attachment A-1) suggest that about one-third of basic research funding should go to the intramural program, but that specific distributions may deviate substantially, depending on technical and management factors, to optimize overall benefits.

More basic research funding is designated to extramural projects, to tap the expertise of universities and industry. At the same time, Air Force laboratory staff report that, to maintain strong in-house research teams, they need more funding. Intramural research is in fact conducted in large part to enable the laboratories to absorb outside advances effectively. Changes in the division of funds between internal and external research would thus have both advantages and disadvantages. However, no persuasive arguments were presented to the committee that a significant change in this division is needed.

Conclusions

In view of the practices reported by the other services, the subcommittee feels that the Air Force administration should consider increasing the percentage of RDT&E funds that go to 6.1 research. Indeed, if this is possible, some of the problems reported by the laboratory staff can be alleviated without changing the balance of intra- and extramural funding.

Strategic Planning

- *Is the general approach to 6.1 strategic planning optimal?*
- *Are Air Force senior leaders sufficiently cognizant of Air Force basic research programs?*

A number of strategic planning processes shape the development of Air Force basic research programs: formal guidance received from SAF/AQ and DDR&E, preparation of the Air Force Research TAP, Tri-Service S&T Reliance documents and the five complementary cross-cutting interlaboratory investment plans (ILIPs, in the areas of electron devices, software, producibility, transient electromagnetics, and environment, safety, and occupational health), and AFOSR's Spring Review presentation to HQ AFMC/S&T Corporate Board. DOD has identified a set of critical technologies, common to all services, that are discipline- or topic- rather than mission-oriented; each service must relate its research program to these DOD critical technologies.

However, for all these processes' value, they do not provide adequate mission-specific strategic planning for the Air Force. The unique advantage of Air Force research and research management is the ability to conduct and capitalize on the research and technology that is critical to Air Force needs.

For example, given the Air Force planning blueprint of "Global Reach—Global Power" and present programmed resources, the Air Force will be flying many of its current aircraft well into the 21st century.[2] Achieving this goal will require strong maintenance and technology insertion programs to ensure viability, survivability, and effectiveness. The Air Force now has such programs, in maintenance in the operational commands, in modification, repair, and remanufacturing in the Air Logistics Centers, in engineering in the product centers, and in technology in the laboratories. Its long-established Aircraft Structural Integrity Program (ASIP) is a recognized model for the technical management of aging aircraft, not only by the Air Force, but also by DOD, FAA, NASA, and others.

Yet there are still important technical unknowns in supporting aging aircraft (e.g., the relation of micro- to macroscopic material properties in the formation and propagation of cracks, the behavior of structures composed of different materials in which there is multiple-site damage, and some of the fundamental phenomena of interest for corrosion and nondestructive evaluation).[3] Many of these technical unknowns of particular interest to the Air Force must be addressed through basic research. The Air Force has already made commendable efforts in its emphasis on some of these areas of research.

---

[2] See *Global Reach--Global Power: The Evolving Air Force Contribution to National Security*, White Paper, Department of the Air Force, December 1992.

[3] While AFOSR supports little research in the area of nondestructive evaluation, it provided important support to a successful recent workshop sponsored at an Air Logistics Center, with participation of the FAA, NASA, DOD, and others.

A "Strategy to Task" approach, in which operators and researchers exchange their experience and knowledge, has been used with some success for mission-oriented technology planning.[4] This approach might be usefully applied to planning Air Force basic research.

Strategic research planning in the new environment will require an increased focus on Air Force mission needs, but it should be emphasized that this focus should not lead to using 6.1 funds for applied research. Basic research can be more oriented to mission needs and still be fundamental science (e.g., basic science research relating to corrosion). Moreover, to achieve the revolutionary advances of the future, some basic research must be strictly science-driven, pursued without concern for application.

Conclusions

Especially in view of constrained defense budgets, strategic planning for basic research should take better account explicitly of long-term Air Force mission goals. Good planning now requires strong mission as well as discipline orientations. Mission-oriented planning should reflect the judgment of AFOSR, the laboratories, the Air Logistics Centers, the operational Air Force commands, and other representatives of the Air Force R&D community. Such strategic planning would help identify and pursue the technical thrusts and research programs that may best benefit the future Air Force (e.g., a focused research program on the problems of aging aircraft).

A small portion of Air Force basic research funding should be set aside to pursue especially innovative research, regardless of any applications it promises.

The practice of briefing the basic research strategic plan to senior Air Force leaders at AFMC and Air Force Headquarters is strongly endorsed, along with other measures that enhance high-level understanding of the potential of basic research.

Development of Research Programs

- *How can the formulation of Air Force basic research programs be improved?*
- *Should the Air Force laboratories play a greater role in program development?*

---

[4] See Glenn A. Kent and William E. Simons, 1991, A Framework for Enhancing Operational Capabilities, RAND, Santa Monica, California.

- *Should there be greater external peer input to program development?*
- *How can AFOSR best exploit new areas of research, if these areas have no AFOSR advocate?*

Formulation of Air Force basic research programs is now primarily a top-down process. While they receive guidance from a number of sources, AFOSR management staff largely formulate the research program, which is then conveyed to the Air Force laboratories and extramural researchers.

According to AFOSR's Guiding Principles (Attachment A-1), AFOSR scientific directors make the decisions on funding shifts, policy matters, and program quality. The AFOSR program manager is responsible for funding decisions, annual reporting, and initiation and guidance of research, and serves as the principal AFOSR link to the Air Force laboratories.

Two kinds of advisory bodies have been formed to assist AFOSR in program planning, the AFOSR Research Council, which advises the AFOSR Director, and the Technical Advisory Boards, which advise AFOSR scientific directors. However, the program manager still appears to be the primary interface with the labs.

Once general research plans are formulated, the Air Force laboratories (and separately, external labs) propose specific research within the identified interest areas. Again, AFOSR makes the final funding decisions. These decisions are sometimes made in consultation with the laboratories, but in other cases they are made effectively by AFOSR program managers alone. Discussions with Air Force laboratory staff indicated they strongly desire to make greater contributions to this process.

Based on all the information provided, the subcommittee believes that there could be greater partnership between AFOSR and the laboratories in formulating research programs. There is some danger that AFOSR may be acting at times in an isolated or autocratic manner, and Air Force laboratory personnel could contribute greater knowledge of special Air Force technical requirements, beneficially shaping basic research programs. AFOSR should fully exploit, insofar as possible, the specialized expertise it has at hand. Additionally, laboratory staff would likely be better facilitators of the transition of research results, when they have had a greater hand in planning the research.

At the same time, there are potential dangers in seeking greater laboratory input: potential conflicts of interest (which may be worsened by the budgetary pressures that lead to emphasizing in-house research at the expense of extramural research), a slide into outmoded research interests or approaches, and the undesirable diffusion of leadership (e.g., in the form of poor coordination of intra- and extramural work, or of tolerance of weak components). In short, greater input from laboratory personnel would be valuable, but should be sought with care.

AFOSR research managers also vary greatly in the way they seek external input in program formulation. (As the Guiding Principles point out, "excellence is determined by the AFOSR scientific directors, augmented by peer reviews as necessary.") In some AFOSR areas, such as Life and Environmental Sciences, Chemical Sciences, and Atmospheric Sciences, external peer review of proposals is a formalized process. AFOSR personnel involved in these more formal reviews observe that, for their own areas of research, these reviews are quite helpful in providing independent, unbiased input, a view in keeping with the consensus and practice of the larger research community.

In AFOSR research management more generally, however, external peer review is obtained only ad hoc. This fact is of particular concern to the subcommittee. External input to Air Force research programs can be invaluable to ensure that programs remain at the leading edge of research, leverage the work of others, avoid redundancy, and are of the highest quality in other respects. As noted by AFOSR personnel and many others, formalized external reviews can present their own problems, including lack of flexibility, burdens of time, expense, and administrative work, and the potential introduction of biases, as in any review.

These considerations together lead the members of this subcommittee to hold a range of views. At one end of the spectrum, some think that external peer reviews should be regularized across AFOSR. At the other, some think that formal arrangements might inhibit the creativity and motivation of AFOSR research managers, and that therefore a better approach would be to encourage program managers to achieve optimal external input, in their own chosen ways, through continuing education, performance reviews, and salary determinations. The use of research databases, especially those of the other services and relevant federal agencies, could provide another valuable type of information about external research. Regardless of specific view, however, all subcommittee members agree on the value of well-designed external input to AFOSR program planning, for all the reasons noted above. The group as a whole also found that such input appeared weak in some AFOSR areas.

Given the very significant technical decision-making authority of AFOSR research managers—which would remain even with the changes suggested here—great effort should go toward ensuring that the best people are hired for these positions and that they have the resources and performance requirements to do an optimal job.

Again, because of centralization of authority in Air Force basic research planning, there is greater risk that leading-edge and other important research may go unfunded. Basic research is increasingly widely conducted and diverse. Yet if proposed research is not of direct interest to an AFOSR program manager, support for the research is likely to be minimal. AFOSR has been very slow to move into new areas of research, even when given guidance to do so. SAF/AQ provided guidance to build research supporting logistics several years ago. But progress has been delayed because no program manager understands or advocates such research.

Additionally, while well-defined steps have been taken to encourage multidisciplinary research, current basic research in areas bearing on logistics and manufacturing may not be sufficient (again, the Air Force would benefit from strong programs in such areas as corrosion, stress-cracking, tribology, artificial intelligence for monitoring systems, and nondestructive evaluation). Greater attention is being given to such research by DARPA and universities, and the Air Force should be concerned to pursue and capitalize on this work.

In short, the present means of formulating the Air Force basic research program has the advantages of strong centralized leadership, but the disadvantages of necessarily quite limited scope. It would appear that some changes in the process might reduce the problems noted.

Conclusions

The Air Force should devise procedures to involve at the "partnership level" parties beyond its own staff in research program formulation. Laboratory personnel and representatives of both universities and industry where relevant work is funded should be part of the partnership. In particular, external review of proposals should be encouraged through appropriate means. (Other specific possibilities might include, as one laboratory scientist suggested, the naming of lab "adjunct program managers" to work in partnership with AFOSR staff.) In any new arrangements, however, care should be taken to avoid the pitfalls noted above and to maintain the valuable coordination that AFOSR provides.

The incorporation of critical new research areas should also be kept in mind in revising program formulation procedures. For example, an interdisciplinary team of program managers could be designated to evaluate proposals in emerging areas of potential importance, with the help of appropriate outside expertise, from the Air Force laboratories and the external research community. A small percentage of the 6.1 budget might also be held back each year to allow the pursuit of new areas. Decisions about such areas could be made by the interdisciplinary team.

Balance of Nearer- and Longer-Term Research Goals

• *Does the Air Force 6.1 program successfully balance the pursuit of both nearer- and longer-term goals?*

Balancing shorter- and longer-term goals is a traditional problem faced by research managers. The distinction between basic work and technology, on the one hand, and development, on the other, is not always clear. For that matter, there is no clear consensus among managers or scientists about the definition of "basic research." Still, some reasonable guidelines can be developed to help avoid confusion concerning these terms.

Regardless of definitional uncertainties, there is no evidence that the Air Force has significantly shifted away from a strong basic research program. However, two related questions arose in the subcommittee's fact-finding about the current program. First, some of those consulted expressed concern that some AFOSR program managers improperly interpret basic engineering science research as "too applied" to be considered basic research. There is evidence to believe, for example, that a number of good extramural research projects have been rejected via such reasoning. Others expressed concern that pressures within the Air Force lead some in-house labs to overemphasize near-term results, forcing a selection of projects that might properly be called "applied."

Conclusions

AFOSR administration should develop its policies and procedures to help program managers avoid arbitrary decisions in determining the "basic" or "developmental" nature of proposed research. Improving this decision making will likely require ongoing, open discussion among AFOSR staff, inasmuch as one natural inclination is to regard the work one knows well as more "basic," and other work as more "applied." One good management response might be to develop a seminar series for AFOSR research managers. Program managers could confront this and a number of other important issues as part of such a "continuing education" program.

One particular Air Force procedure of interest is the annual relevancy review. Relevancy to the Air Force mission is certainly an important factor in judging the value of AFOSR-sponsored work. However, "relevancy" should not be confused with "promising shorter-term results"; that is, a higher weight should not automatically be given to research that should have a more immediate payoff. The fundamental research underpinning broad areas of science and technology—which ultimately supports new and revolutionary technologies—is as relevant as fundamental research in support of current problem-solving.

Technology Transition

• *How can Air Force transition of basic research results to the Air Force technology base be improved?*

The linear model, in which useful 6.1 research results are presumably quickly recognized by 6.2 workers, and so on throughout development, does not always work smoothly. Subcommittee members' site visits (e.g., to Hanscom Air Force Base) suggested that, in some cases, 6.1 researchers work closely and effectively with developers. However, sometimes laboratory researchers are not in touch with 6.2 people in the same lab. The 6.2 and 6.3 engineers frequently have closer ties to engineers in industry or universities. (In fact, the nature of different projects alone tends to produce some variation in the communication of 6.1 researchers and other Air Force researchers.)

Air Force management recognizes this problem. Thus, on occasion, AFOSR has used 6.1 dollars to help the transition, as for a recent research consortium of university and industry groups addressing microwave tubes, funded by AFOSR, and managed by Rome Laboratory. Additionally, in the past two years AFOSR has established an S&T Coordinator program, in which selected program managers are designated to facilitate technology transition between discipline-oriented AFOSR basic research and the multidisciplinary, technology-oriented efforts of the Air Force laboratories.[5]

A difficulty encountered by the subcommittee in their review of transition is that there is no database for evaluating how effective the transition process has been. Examples of successful transitions can be cited, but such examples do not provide an adequate overview or measure of the success of the Air Force transition process.

Conclusions

AFOSR should continue to focus on the issue of transition. One way to do this would be to build on the current S&T coordinator program (the experience and achievements of this group should in any event be considered

---

[5] See also Helmut Hellwig, "Transitioning Research Results: A Challenge in Communication," *Proceedings of the International Conference on Management of Engineering and Technology*, October 27-31, 1991.

in the future development of Air Force transition efforts). The development of a quantitative database on past and continuing progress in technology transition is one important question to explore. If a measure of the effectiveness of existing transition mechanisms can be established, more logical efforts can be applied to improving them.

The Commander of AFMC should develop goals and guidelines for the new process of gathering information on transition, either through the AFMC Technology Executive Officer or through AFOSR. The recent establishment of an AFOSR historian should also be a valuable contribution toward developing this information base.

Some fairly straightforward methods might enhance transition and could be implemented even before any database is developed. One is to ensure that all program managers have up-to-date lists of potential users of 6.1 research within their areas. Appropriate research reports, for both in-house and external projects, should be distributed to the lists. Such report distribution is currently quite variable, depending on the practice of the individual program manager.

Another opportunity to encourage communication between 6.1 researchers and potential users occurs during the annual review meetings. For example, spring and fall reviews could be planned so that potential users could participate in discussions of 6.1 research projects. Such meetings could be widely publicized and held at convenient locations, with sufficient time scheduled for both planned and informal discussions among basic researchers and users.

All AFOSR program managers should be encouraged to help establish communication between researchers and potential users. Often researchers do not know who possible users are; the AFOSR manager must take an active part in helping work out such contacts. Air Force laboratory staff are clearly one important resource that the AFOSR manager could use.

The issue of transition would be an important topic in the "continuing education" program for AFOSR managers proposed earlier. It would be instructive to present case histories, so that program managers could learn more about the techniques that have been most successful and about problems that have hindered transition.

Best Use of Diverse Research Groups

- *How can the Air Force best use the spectrum of research groups, within in-house laboratories, universities, and industry laboratories, that it has at its disposal?*

At present, Air Force research projects could be ranged along a continuum, with one extreme represented by the work of individual researchers for small groups, and the other by collaborative teams involving Air Force laboratory, industry, and university researchers.[6] Again, the optimization of such types of groups is a classic problem in research management.

The subcommittee did not find any evidence that the current Air Force mix is inappropriate. However, some concern was raised by the fact that the mix differs considerably among program managers, depending on the manager's style and personal views about research. This variation is not bad in itself, but if managers can comfortably handle only individual investigators or large research groups, this can be restrictive and fail to capitalize on the best research expertise.

Conclusions

AFOSR should ensure that program managers understand how to handle both small research groups and integrated research teams. Information on related management techniques (e.g., case studies of successful integrated teams) could be incorporated in the "continuing education program" for program managers.

At the same time, other approaches should be pursued to encourage continual exchange of information among Air Force laboratories, universities, and industry, so teams can develop through a self-motivation process. Examples of such approaches are the AFOSR-sponsored Summer Faculty Research Program (SFRP) and the University Resident Research Program (URRP). AFOSR should study these programs to ensure they are successful in building good working relationships between university and Air Force staff. For example, one goal for the summer faculty program should be that university participants continue to interact with Air Force laboratory personnel after returning to universities (e.g., through the participation of university participants in the Air Force funded research program). How well these exchange programs are working in building such relationships is unclear, because no appropriate information base is available to make the judgment. The subcommittee suggests that AFOSR develop this kind of database, so that such programs can be evaluated.

The subcommittee noted that there is no counterpart program to bring industry research staff into Air Force laboratories. In general, owing to the

---

[6] Interservice cooperative research is discussed in Appendix B.

extensive interactions of Air Force researchers with industry at the 6.2 and 6.3 levels, it is easier to open communication channels with industry than with universities (which typically do not participate in these later development programs). Still, AFOSR should consider whether some additional mechanism or program should be used to encourage Air Force laboratory-industry interactions at the basic research level.

Quality Laboratory Researchers

- *What approaches can be used to attract and retain high-quality researchers in the Air Force laboratories?*

The vitality of the Air Force Research program depends on the ability to attract and retain outstanding researchers in the Air Force laboratories. In addition to the research they produce, in-house staff provide an essential communication channel and means of collaborating with external researchers.

Air Force salaries and other benefits are somewhat lower than those of comparable industrial and university laboratories. Efforts to increase Air Force salaries should continue. However, in discussions with laboratory scientists, the subcommittee learned that many find other aspects of Air Force research programs—the excellent facilities and equipment and fewer requirements to write lengthy research proposals—to outweigh the salary deficit.

A related issue is how to bring talented new staff into the Air Force laboratories. The new Palace-Knight program, to increase young doctoral-level scientists and engineers in the laboratories, appears to be an important step taken to attract new staff. However, this program is limited in numbers and the approach of identifying people so early in their academic careers has not yet stood the test of time. Discussions with current young Air Force staff suggested that they are attracted by the same benefits that help retain the older staff.

Conclusions

Cutbacks in funding and the Air Force work force will make it increasingly difficult for Air Force laboratories to maintain an inflow of good young staff. In view of the importance of the issue, ways to overcome any such problems must be found. The Air Force should consider how to maintain state-of-the-art experimental facilities in the laboratories. With current funding cuts, there is a concern that these facilities could rapidly deteriorate. Not only would this seriously hamper lab research, it would make it more difficult to hire top researchers.

Finally, care must be given not to overburden laboratory staff with administrative work and with proposal writing. That is not to say that proposal writing should be eliminated or that service on committees and task forces should be stopped. However, an appropriate balance must be struck. As suggested earlier, the Air Force should encourage more planning and management input from the laboratories, but at the same time not overburden productive scientists with administrative matters. Air Force administration and the chief scientists at the laboratories could help ensure that adequate support staff is available to avoid undue burdens on research staff.

ATTACHMENT A-1

Guiding Principles
for
The Intramural Basic Research Program Sponsored by AFOSR

1. Mission: The Air Force Office of Scientific Research (AFOSR) has single manager responsibility for planning, managing, implementing, and controlling the USAF Defense Research Sciences program under Program Element 61102F. In that role, AFOSR executes the policy prescribed by AFSC Regulation 23-15, 17 June 1988. In addition, AFOSR shall work closely with the Air Force laboratories to nurture and support quality research and to coordinate intramural and external research results to promote transition of research to the Exploratory Development programs of the laboratories.

2. Purpose of Intramural Tasks: To perform research; contribute to the knowledge base; augment technology transition; provide and develop expertise in fundamental S&E; attract and develop talent; and help assure relevancy of the extramural program.

3. Scope of Intramural Program: The intramural program is defined as funded tasks in those Air Force organizations that fall under the management guidance of the Technology Executive Officer (TEO); currently this includes WL, AL, PL, RL and AFCESA/RA. The total investment should be approximately one third of the discretionary portion of the 6.1 DRS funds. The discretionary portion is arrived at by subtracting AFOSR support funds (including those for detachments), withholds by parent organizations, Congressionally mandated specific programs, etc. The detailed distribution among the laboratories, their directorates, and other organizations may substantially deviate from the overall one-third goal; the detailed distribution is governed by technical and management considerations aimed at optimizing overall benefits to the Air Force.

4. Execution of Intramural Program: The intramural program is subdivided into laboratory tasks each headed by a task manager. To achieve its purpose, the intramural program must, primarily, be carried out by Government employees within the laboratories of their employer. Visits and working stays by others on the laboratory premises as well as by Government employees elsewhere are encouraged. To the degree necessitated by hiring constraints, on-site contractor employees are acceptable. Extramural contracts or grants (research performed by others off premises, foreign or domestic) are to be

used only to directly support or complement (as part of a coordinated program) on-going in-house research programs. This includes collaborative work with external researchers.

5. Laboratory Interface:

a. The AFOSR program manager (PM) is the primary interface to the laboratory tasks within a PM's "portfolio" (AFOSR subarea). Funding decisions, annual reporting, initiation of research, guidance of research etc., are made at this level. A PM works with laboratory staff, laboratory task managers, division chiefs and the directorate chief scientists.

b. AFOSR scientific directors are the higher level interface. Decisions on funding shifts between AFOSR subareas and decisions involving policy matters, as well as on the quality of the program, will be made at this level. Scientific directors will typically interact with the directorate directors, directorate chief scientists and the laboratory chief scientists.

c. To aid in strategic research planning, decision making, vectoring of limited resources, and arbitration of differences in priorities, two advisory boards have been formed: the Technical Advisory Boards (TABs), providing advice to AFOSR scientific directors, and the AFOSR Research Council, providing advice to the director of AFOSR.

6. External Interface: To promote technology transition from 6.1 to laboratory 6.2 programs, the AFOSR program managers and scientific directors will (1) promote collaborative programs between laboratory scientists and external researchers, (2) promote visits and scientific exchange between university and laboratory scientists, and (3) sponsor, at least annually, joint AFOSR-Air Force laboratory topical workshops for the exchange of technical information between Air Force laboratory researchers and external researchers funded directly by AFOSR; such workshops may be topically focused and may be open to others such as to the other Services.

7. Funding Policy:

a. Research in Air Force laboratories will be initiated based on a written request which will be evaluated by AFOSR; progress will be reported annually (See AFOSRR 80-7). Substantial changes in the scope or direction of research will be considered equivalent to an initiation of new research requiring appropriate documentation.

b. There is no automatic termination of intramural research. If a laboratory task must be terminated for reasons other than natural completion or personnel departure, coordination for termination should be accomplished through the appropriate AFOSR TAB(s) and, if required, through the AFOSR Research Council.

c. Funding may be handled through a Budget Authority (BA) or other funding instrument as authorized by the USAF.

d. AFOSR generally will accept overhead charges by the Air Force laboratories associated with management and support of research; however, unreasonable additional withholds, not reconcilable with carrying out basic research, may be grounds for AFOSR to not fund intramural research.

8. Reviewing Research:

a. The responsibility for ascertaining excellence of research and its relevance is delegated by the Air Force to AFOSR. In carrying out its management duties, AFOSR must rely on competent counsel. For relevance, this counsel primarily comes from senior Air Force laboratory staff. Excellence is determined by the AFOSR scientific directors, augmented by additional peer reviews as necessary.

b. AFOSR will schedule two oversight processes each year. The Fall Reviews are for the purpose of evaluating the entire basic research program for excellence and relevance. The Spring Reviews deal with programmatic direction and planning, and include the selection of new programmatic initiatives for funding. The AFOSR Research Council and the Technical Advisory Boards participate in these processes.

9. This document supersedes the following MOUs:

a. MOA between AFOSR and the Air Force Engineering and Services Laboratory, 15 August 1988

b. MOA between AFOSR and the Air Force Space Technology Center, 11 April 1989

c. MOA between AFOSR and the Human Systems Division, 27 September 1988

d. MOA between AFOSR and Rome Air Development Center, 27 September 1988

f. MOA between AFOSR and the Wright Research and Development Center, 4 October 1989

g. MOA between AFOSR and the Air Force Armament Laboratory, 30 August 1988

Helmut Hellwig

HELMUT HELLWIG
Director

CONCURRENCE:

AL/CA (For Armstrong Laboratory) George C Nicolai DATE: 27 Feb 92

PL/CA (For Phillips Laboratory) Joseph Janni DATE: 10 Mar 92

RL/CA (For Rome Laboratory) Fred Diamond DATE: 10 Feb 92

WL/CA (For Wright Laboratory) G. Keith Richey DATE: 20 Feb 92

AFCESA/RA Michael D. Katona DATE: 7 Apr 92

Appendix B:
A Comparison of Research Management Practices at the Air Force Office of Scientific Research and Other DOD and Federal Agencies

Paul F. Parks, *Chairman*
Albert J. Baciocco
Erich P. Ippen
Christopher C. Green

The subcommittee was charged with comparing the Air Force's research management practices and those of other government organizations, to determine what lessons these practices might offer for Air Force management of basic (6.1) research. The subcommittee was also asked to consider, as possible, related issues of research leveraging and redundancy.

In conducting its study, the subcommittee reviewed the research management practices of both Department of Defense (DOD) and other federal agencies. Members of the subcommittee were briefed by the director, program managers, or other senior managers of the Air Force Office of Scientific Research (AFOSR), Army Research Office (ARO), Office of Naval Research (ONR), Office of the Secretary of Defense (OSD), Defense Advanced Research Projects Agency (DARPA), Air Force laboratories, Air Force Scientific Advisory Board (SAB), National Science Foundation (NSF), U.S. Department of Energy (DOE), and National Aeronautics and Space Administration (NASA) (see Appendix D for a list of these meetings).

DOD AGENCIES

The briefings on AFOSR, ARO, ONR, and DARPA led the subcommittee to focus especially on several research management issues in the context of DOD organizations: the reporting level of the research organization within the greater DOD organization; 6.1 resource management issues, including the level and allocation of 6.1 funding, research management personnel, and discretionary laboratory funding; and interservice cooperative research.

Reporting Level of the Research Organization

In response to recent budgetary and geopolitical trends—and to many recent studies of defense research management—all three military services have been reorganizing their laboratories and R&D-related processes over the past few years.[1]

Army

The Army has combined many of its laboratories and changed its lab command structure. Under the new structure, the Army Materiel Command's (AMC) Laboratory Command (LABCOM) and its seven corporate laboratories were consolidated in the new Army Research Laboratory (ARL). The Director of ARO, which manages extramural Army research, no longer reports through LABCOM, but instead directly to AMC Headquarters (Figure B-1 shows the new Army organizational structure). The Army also continues to maintain laboratories in the Army Medical Research and Development Command and Army Corps of Engineers, and conducts additional research through its Research, Development, and Engineering Centers (RDECs).

An important advantage of these organizational changes, beyond the greater integration and efficiency they promote, is that basic research opportunities and needs, especially those relating to extramural research, are given greater visibility within the Army structure. The Commanding General of AMC reports directly to the Chief of Staff of the Army and coordinates 6.1 programs with the Assistant Secretary of the Army for Research, Development and Acquisition. The Director of ARO is now also a voting member of the AMC Science and Technology Board of Directors, which coordinates basic research and related activities, and whose other members include the directors of ARL and the RDECs, as well as the AMC Chief Scientist and representatives of the Department of the Army and Army Training and Doctrine Command.

[1] For an overview of these developments, see Federal Advisory Commission on Consolidation and Conversion of Defense Research and Development Laboratories, Report to the Secretary of Defense, September 1991. Other important recent reports include the Defense Science Board 1987 Summer Study on Technology Base Management, December, 1987; and U.S. Congress, Office of Technology Assessment, Holding the Edge: Maintaining the Defense Technology Base, U.S. Government Printing Office, June 1989.

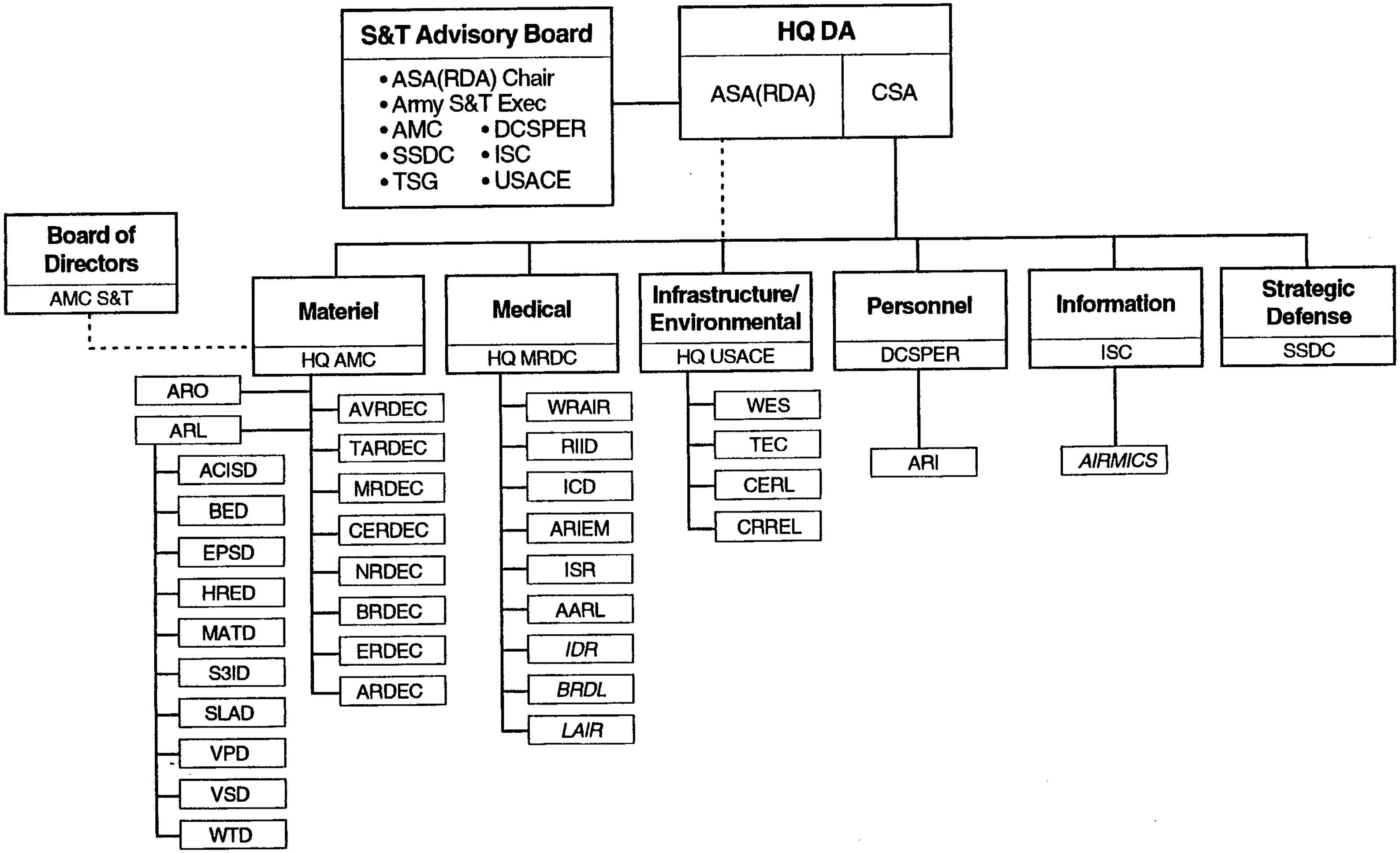


FIGURE B-1 Army organization for research management (adapted from Army Science and Technology Master Plan, Headquarters, Department of the Army, November 1992; solid lines are reporting lines, dotted lines are lines of coordination; for explanation of acronyms, see glossary).

Navy

The recent Navy Laboratory Consolidation Plan was developed to consolidate, realign, and downsize the Navy's R&D centers, merging them with support engineering activities and T&E centers, to form four Navy warfare centers. The two laboratories of the Office of Naval Research (ONR), which is responsible for 6.1 programs, have also been consolidated: the Naval Research Laboratory (NRL) and the Naval Oceanographic and Atmospheric Research Laboratory (NOARL) were combined at the beginning of fiscal year 1993 to form a new NRL.

In keeping with long-established practice, the Chief of Naval Research will continue to be responsible for the planning and execution of the entire Department of the Navy science and technology enterprise, including basic research through the ONR. This position has no direct counterpart in the other services (Figure B-2 shows the Navy research organizational structure). Along with other characteristics of the Navy research enterprise, this position has encouraged appropriately high-level attention to basic research. The Chief of Naval Research reports directly to the Assistant Secretary of the Navy for Research, Development and Acquisition.

Air Force

The Air Force has just undergone a major realignment of its laboratories and research management. The previous 14 Air Force laboratories were combined into 4 "super" laboratories: Wright (aircraft), Phillips (space and missiles), Armstrong (human systems), and Rome (command, control, communications, and intelligence, or "C^3I") laboratories. This realignment reflects the move from a technology-oriented to a systems-oriented, multidisciplinary laboratory approach, and is designed to promote efficiency.

Effective July 1, 1992, the management structure under which AFOSR operates has also been changed. Air Force Systems Command (AFSC), to which AFOSR reported, was combined with Air Force Logistics Command (AFLC), to form the new Air Force Materiel Command (AFMC).

Under the previous Air Force organization, the AFOSR Director reported to the AFSC Deputy Chief of Staff for Technology, who reported to the AFSC Commander. The Deputy Chief of Staff, as Technology Executive Officer (TEO), also reported to the Assistant Secretary of the Air Force for Acquisition. The advantage of the TEO role is in providing integrated S&T investment strategy guidance and a dedicated lab systems advocate. These particular features of the Air Force command structure remain fundamentally unchanged (Figure B-3 shows the new Air Force structure).

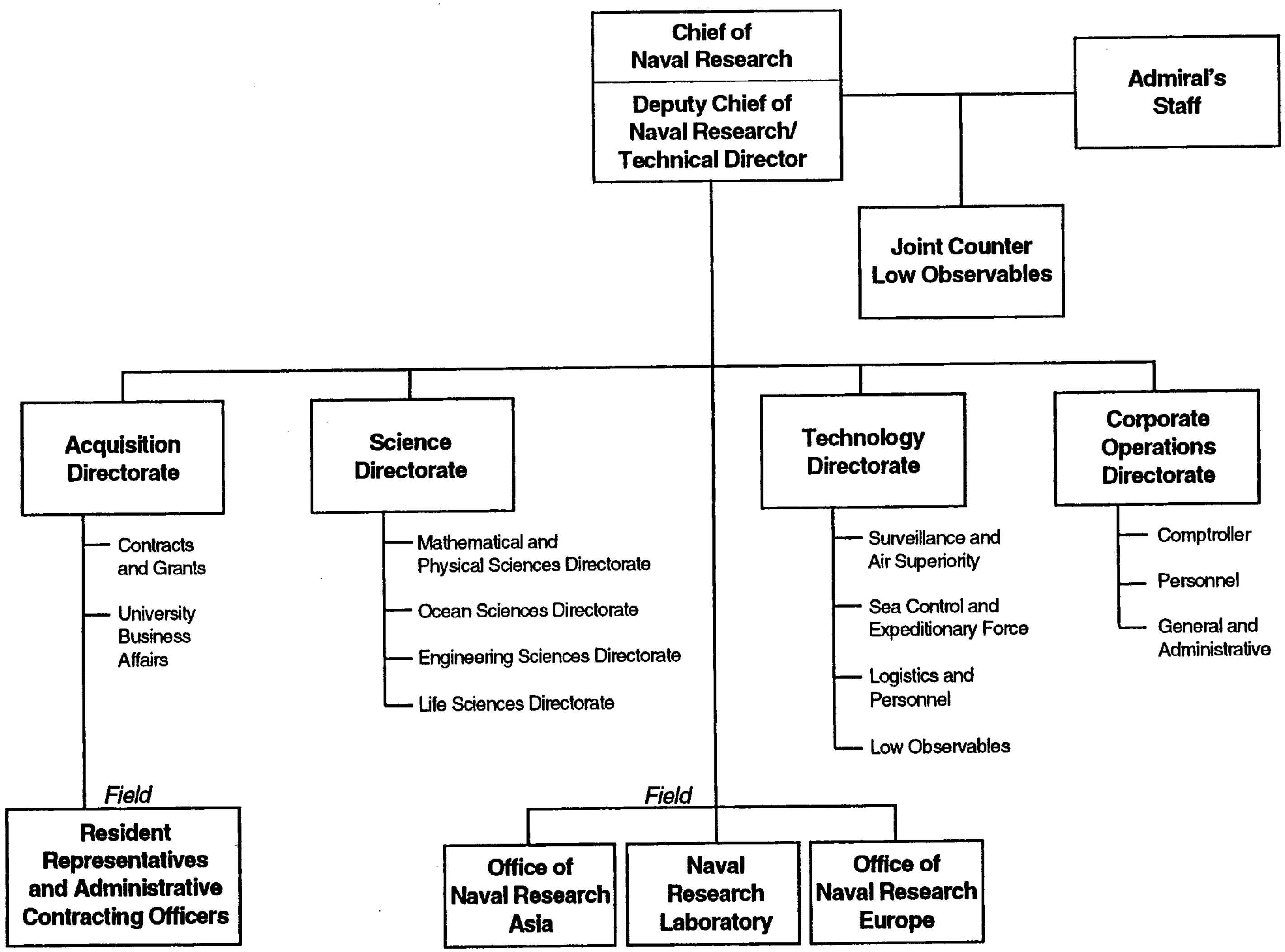


FIGURE B-2 Navy organization for research management (adapted from material provided by the Office of Naval Research).

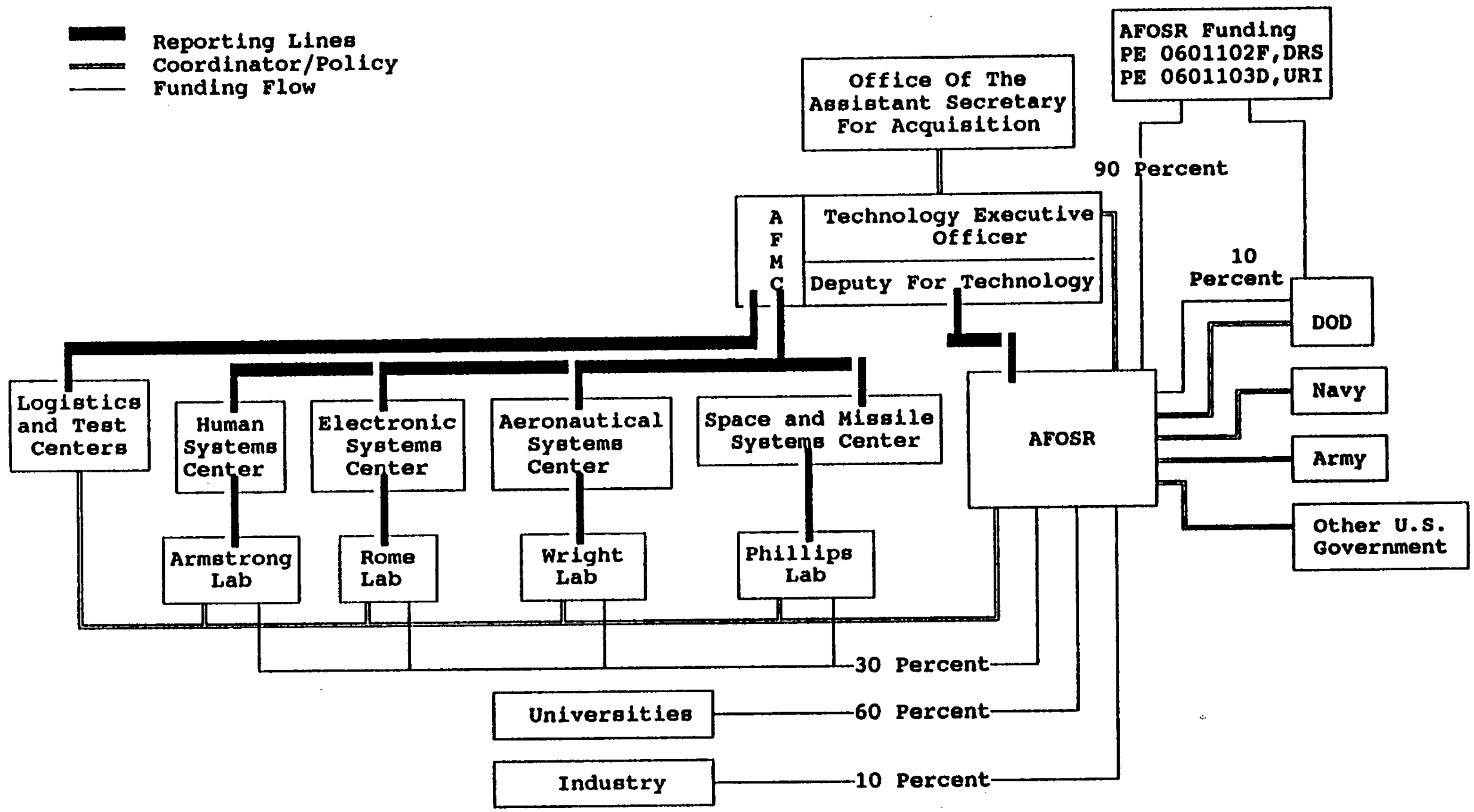


FIGURE B-3 Air Force organization for research management (Headquarters, Air Force Materiel Command).

However, with the formation of AFMC, AFOSR has been placed within a much larger, more diverse organization. In 1990, AFSC personnel totaled about 44,000; in 1992 (following the Air Force reorganization), AFMC personnel totaled almost three times that, or nearly 129,000.[2] Representatives of both the Air Force Scientific Advisory Board and AFOSR, as well as the subcommittee, have some concerns about the effect of this change on AFOSR's ability to manage the Air Force basic research programs.
Moreover, AFOSR is now reporting to a one-star general under AFMC, while under AFSC it reported to a two-star general; ONR reports to an admiral of two-star rank, who reports directly to the Office of the Secretary of the Navy; and ARO was recently "upgraded" to three-star reporting. These differences in reporting level are not of concern in and of themselves. However, reporting level in part determines the visibility of any DOD organization within DOD (e.g., in assessing the relative importance of programs), and thus also its visibility externally, that is, academia and industry about the organization's standing.

The subcommittee is concerned about the effects of the Air Force reorganization on AFOSR, and especially about the combining of AFSC and AFLC to form AFMC. This reorganization places AFOSR in a much larger, more diverse organization where it may be further removed from senior leadership, with a resulting loss of critical connection to planning and policy. The post-Cold War world presents fewer military challenges in important respects, but the importance of basic research to the Air Force mission is still as vital. There is growing worldwide availability of high technology, use of such technology in weapons systems, and unpredictability of threats to the national interest.

Defense Advanced Research Projects Agency

The subcommittee also looked at DARPA, to see what lessons it might offer for organizational structure. However, in this and other points of comparison, the subcommittee found that DARPA's specialized focus (mainly high-risk demonstration and fieldable advanced technical systems) and related operations fail to provide any readily determinable lessons for Air Force basic research management.

---

[2] Source of figures, AFMC Headquarters.

Conclusions

The importance of basic research to the Air Force's long-term warfighting capabilities must be recognized by its organizational structure. For this reason, it is critical that the Air Force basic research organization be positioned to inform and be informed by the policy, budget, and program decisions that may affect the contributions of basic research to the Air Force mission. Within the current structure, this goal might be best accomplished by ensuring the TEO maintains his current level of responsibility and role, and by continuing to assign TEO responsibilities to a person who, by virtue of training and background, demonstrates strong knowledge and appreciation of basic research.

Management of Basic Research (6.1) Resources

The Army Research Office manages only the Army's extramural basic research programs, including its Centers of Excellence (e.g., in electronics and rotorcraft), which consist mainly of university research. Thus, ARO manages only about one-third of the Army's 6.1 funds. The other two-thirds are allocated directly to the Army laboratories (primarily by Army Materiel Command, but also by other commands), including funding for In-House Laboratory Independent Research (ILIR). ILIR funds are lab discretionary funds, to pursue projects of high risk, but high potential payoff, and innovative approaches to research. A significant fraction of the funding allocated directly to Army laboratories also goes out to support university and industry research.

In contrast to ARO, the Office of Naval Research manages all Navy 6.1 funding, both intra- and extramural, that is, allocations to universities, industry and other government, and Navy laboratories, including ILIR-funded work. For fiscal year 1992, the breakdown of Navy research performers, by percentage of the ONR budget, was as follows: universities, 58 percent; Navy laboratories, 30 percent; and industry and other government, 12 percent.[3] (Figures for 1990 and 1991 were also close to these values.)

In the Air Force, AFOSR also manages all 6.1 funds, with the exception of ILIR funds, which are managed by the laboratories. Current AFOSR guidance suggests that about one-third of the Air Force basic research (Defense Research Sciences) funding should go to the intramural program. (See Attachment A-1 for the full text of this guidance document, which also spells out specific roles for the management of Air Force intramural basic

[3] Source of figures, Office of the Chief of Naval Research.

research.) As in the other services, Air Force basic research funds that are allocated to the laboratories are sometimes used to support outside work.

The three services' different ways of distributing 6.1 funds each have their own advantages. Some are noted in the discussion that follows. However, the subcommittee saw no reason to question the general Air Force practice in this area, that is, AFOSR's designation as "the single manager for the Defense Research Sciences program" (e.g., in contrast to Army practice).

According to information provided by DOD and the services' offices of research, Army 6.1 funding during fiscal year 1992 is approximately $197 million, Navy 6.1 funding $422 million, and Air Force 6.1 funding $203 million (Figure B-4). These values represent 3.6 percent of the Army's total Research, Development, Test and Evaluation (RDT&E) funding, 4.2 percent of the Navy's; and 1.5 percent of the Air Force's (Figure B-5). Thus, the Air Force appears to commit a significantly smaller percentage of its total RDT&E funds to basic research than either of the other two services. The subcommittee was not briefed on the reasons for this discrepancy, nor was it able to investigate this complex subject in satisfactory depth. Further study of the issue may be in order.

As Figure B-4 shows, DOD funding for basic research has been reasonably stable in constant dollars over the past decade. Stability of funding is critical for basic research, in which important results are generally less predictable and seen over a longer term than in applied research. Briefers to the committee indicated that the Air Force is attempting to maintain the stability of basic research funding, even in the face of likely severe budget cuts over the next several years. This goal is both desirable and practical, if the benefits of basic research are to be achieved.

At the same time, the subcommittee is concerned that, as often occurs in such cases, budgetary trends have increased the pressures to allocate a greater fraction of Air Force basic research funding to in-house laboratories. Strong intramural basic research is essential for mission-specific work. But an equally or more important function of Air Force intramural research is to help Air Force laboratories absorb the far more extensive research advances in universities and industry.

The Air Force must continue to capitalize well on the much greater body of outside research. Moreover, extramural research is generally highly leveraged, financially and intellectually. In the case of university research, it additionally prepares the S&T work force on which the future Air Force depends. For these reasons, the subcommittee would not support any change in policy to direct a greater fraction of Air Force basic research funding to intramural research. In reviewing AFOSR's competitive processes, the subcommittee noted that the Air Force laboratories provide important feedback about the results of AFOSR-sponsored research (as users and raters

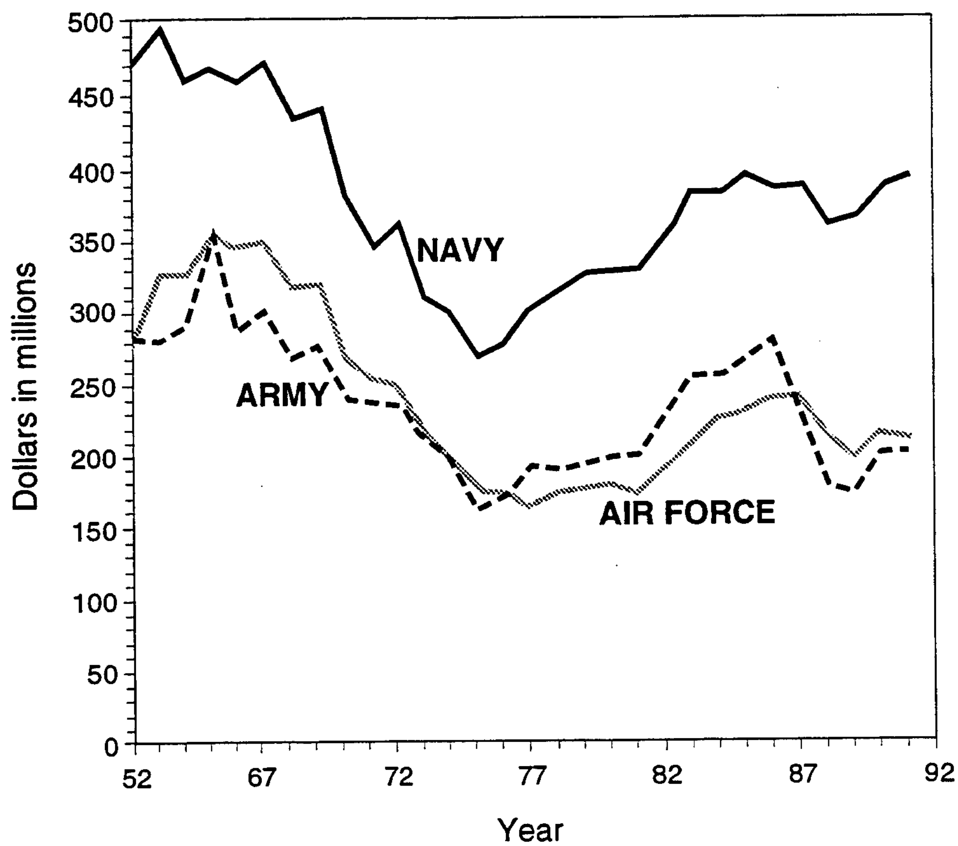


FIGURE B-4 Service basic research budgets, in constant 1990 dollars (DOD Office of Research and Laboratory Management).

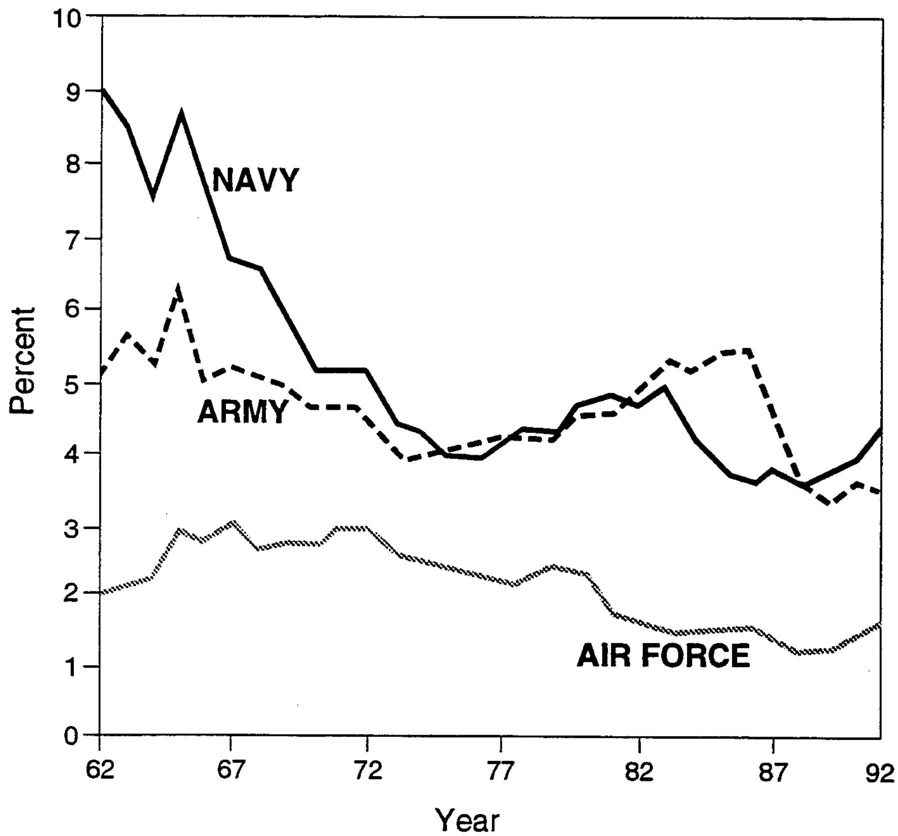


FIGURE B-5 Service basic research budgets, as a percentage of service RDT&E (DOD Office of Research and Laboratory Management).

of research results, and as enablers of technology transfer). At the same time, the laboratories receive basic research funding from AFOSR. Thus, to avoid conflicts of interest, care should be taken in such arrangements to ensure that the laboratories do not exercise undue influence over allocations of Air Force 6.1 funding.

While the primary driving force for research in the laboratories and extramural programs should be long-term Air Force needs, as formulated by Air Force leadership, the subcommittee also supports the recommendation of the 1983 Federal Laboratory Review Panel (reaffirmed by the 1987 Defense Science Board study Technology Base Management, earlier cited) that "at least 5%, and up to 10%, of the annual funding of the federal laboratories should be devoted to a program of independent research and development at the laboratory director's discretion." According to such recent studies, and also in keeping with observations to the subcommittee and its own experience, this management flexibility provides the basis for much creative work. Discretionary funds are important, as the DSB study observed, to maintain the vitality of the laboratories. ILIR funds are one important kind of such discretionary funds and should be protected. At the same time, visibility on this work must be afforded to the rest of the Air Force research community, in particular to AFOSR.

Air Force laboratories often contract with local universities for analytical, engineering, and other services using basic research dollars. The subcommittee is concerned because these funds are not competitively awarded. In fact, based on the information provided, two issues arise about the current practice: are these research dollars well used, and do they support what is properly considered basic research? The subcommittee believes such funds should be awarded through appropriate competitive processes and as 6.1 dollars.

Good basic research programs require highly skilled and creative managers, who hold their positions long enough to see research programs through. This requirement is stronger in the case of Air Force basic research than in other environments, in that Air Force basic research managers have great technical and decision-making authority. The program manager is the main AFOSR interface to laboratory tasks within a given technical area, and has primary responsibility for basic research funding decisions, annual reporting, and initiation and guidance of research (again, see Attachment A-1).

It has long been recognized throughout DOD that the need for highly qualified, stable technical leadership is difficult to achieve through the rotation of military officers.[4] Moreover, the committee also heard some reports that the Air Force fails to look on research management assignments as positive career moves (though this view was not universal).

An unwritten policy at AFOSR is that each directorate should have two military program managers; together, they represent 25 to 30 percent of all AFOSR program managers. AFOSR reports no significant difference in performance between its military and civilian research managers. Other observers have also pointed out that military research managers provide useful perspective on Air Force field needs.

However, based on all available evidence, the subcommittee believes that the more effective way to ensure program quality and stability and organizational memory is generally through the recruitment of distinguished civilian leaders as basic research managers. Longer tours of duty might also be considered for military research managers, and their career opportunities should be good. Program managers should have adequate training and experience (including technical management training and 3 to 10 years of technical management experience). Above all, the Air Force should continue to guarantee that its research managers demonstrate the high-quality technical leadership that AFOSR now attributes to them.

Conclusions

The subcommittee reached the following conclusions based on its comparative review of 6.1 resource management:

1. The subcommittee strongly supports the Air Force policy of maintaining 6.1 funding at no less than its current level adjusted for inflation. Stability of funding is essential to the welfare of basic research programs, which, by their nature, are long-term commitments. Funding stability is also critical to maintain Air Force core competencies.

2. The subcommittee does not support of any change of policy to direct a greater portion of 6.1 funding to the laboratories. While intramural research plays its own critical roles, extramural basic research represents a much more extensive body of scientific expertise. It is also usually highly leveraged, in funds, equipment, and intellectual resources. Additionally, university research prepares the future Air Force scientific work force through the support of graduate and postdoctoral programs. Beyond taking these factors into account in its allocations to intra- and extramural programs, the Air Force should

---

[4] For related discussion, see the 1991 Report to the Secretary of Defense and 1987 Defense Science Board report previously cited.

distribute its 6.1 funds based simply on the value of the research to the needs of the Air Force technology base, the quality of the research, and the quality of the researchers.

3. In general, the Air Force should ensure program quality and stability and organizational memory by emphasizing the recruitment of experienced, technically proficient, civilian leaders as managers of its basic research programs. For the same reason, longer tours of duty should be considered for military research managers, and they should be assured good career opportunities. All research managers should have strong skills and experience in technical management (including technical management training and 3 to 10 years of technical management experience).

4. The subcommittee strongly supports the annual budgeting of independent research and development funds, to be used at the discretion of the Air Force laboratory directors. This funding provides the flexibility that allows the development of innovative ideas. Such discretionary funding, including ILIR funding, should be protected. At the same time, AFOSR should be given review responsibility for ILIR work, to help provide a common standard for quality and to assist in the integrated planning of Air Force research, especially to avoid research redundancy.

Cooperative Research

The Air Force's effective management of basic research depends significantly on the degree to which it capitalizes on the work of others, including that of the other military services. For this reason, the subcommittee also looked at some of the interservice cooperative research in which the Air Force is participating.

In October 1989, Deputy Secretary of Defense Donald Atwood challenged the services to create new approaches to S&T management, to increase efficiency and reduce unwarranted overlap in the RDT&E activities of the military departments. This challenge led to the Tri-Service S&T Reliance project, as well as to the laboratory consolidation studies for the three services whose results were reviewed above.[5]

Tri-Service S&T Reliance issued from Project Reliance, a joint study of the Army and the Air Force on the consolidation and collocation of their R&D efforts in selected technology areas. Tri-Service S&T Reliance expanded

[5] For more background on the Reliance Project, see Joint Directors of Laboratories (JDL), "Tri-Service Reliance in Science & Technology," White Paper, January 1992; and JDL, *Tri-Service Science & Technology Reliance: Annual Report, December 1992.*

this approach to include the Navy, initiating some of the most significant restructuring of the technology base in the past 40 years.

Tri-Service S&T Reliance consists of a set of formal agreements among and implemented by the military departments for joint planning, collocated in-house work, and lead-service assignment, covering most non-service-unique 6.1, 6.2, and 6.3A programs. Reliance is also a formal process, authorized by each service Acquisition Executive and approved by the Deputy Secretary of Defense, to streamline the S&T programs of the military departments and better plan the national defense S&T investment. Responsibility for implementing Reliance has been assigned to the Joint Directors of Laboratories (JDL).

Beyond reducing unwarranted duplication and increasing efficiency, goals of Reliance include ensuring a critical mass of resources to develop world-class products, and preserving mission-essential capabilities.

Six categories of interservice reliance were envisioned: coordination, joint efforts, collocation, consolidation, competition, and service-unique work.[6] Figure B-6 presents the technology areas addressed by working groups during the study phase of this project, and the oversight bodies of these areas. The study phase of project Reliance resulted in formal service agreements for joint planning, collocated research, or consolidation under a lead service for each technology area that is not service-unique.

The results of these agreements were as follows:

- In 71 technology areas/subareas/sub-subareas, the services will jointly plan the work to be conducted at separate service locations, as contrasted with the 6 such cases previously.
- In 105 technology areas/subareas/sub-subareas, work will be collocated to various single-service sites for program execution, as contrasted with the 13 such cases earlier.
- Service management leads will be designated for 10 technology areas/subareas/sub-subareas, an increase of 1 over the past.

---

6 Coordination has traditionally been the most common type of interaction among the services, represented by the many coordination bodies developed over the decades. Joint efforts are planned and conducted jointly, but the involved services can execute tasks at separate locations and they retain separate funding control. Collocation is in-house task execution through a single service, but with all services maintaining separate funding control. In consolidation, a lead service manages the program and all related S&T funds are transferred to the lead service. Competition refers to in-house task execution that is competed among the service performers, with all services retaining funding and performer-decision control. Service-unique work is that work peculiar to a given service, for which no interservice reliance is required or appropriate.

JOINT DIRECTORS OF LABORATORIES

Aeropropulsion
Air Vehicles (Fixed Wing)
Air Vehicles (Rotary)
Astrometry
Chemical and Biological Defense
Clothing, Textiles and Food
Communications, Command and Control
Conventional Air/Surface Weaponry
Electro-Optics
Electronic Devices
Electronic Warfare
Environmental Sciences
Advanced Materials
Explosive Ordnance Disposal
Fuels and Lubes
Ground Vehicles
Integrated Avionics
Nuclear Weapons Effects
Radar
Ships/Watercraft
Small Arms
Software
Space
Unmanned Ground Vehicles
Directed Energy Weaponry

ASBR

Medical

TAPSTEM

Manpower and Personnel
Training System

JOINT

Civil Engineering
Environmental Quality

FIGURE B-6 Technology areas addressed by project Reliance, with their oversight bodies for implementation (Joint Directors of Laboratories; the area of advanced materials was added during the implementation phase of project Reliance).

• A new management and planning structure will implement and verify compliance with Reliance agreements through the Joint Directors of Laboratories (JDL), the Armed Services Biomedical Research, Evaluation and Management (ASBREM) Committee, the Training and Personnel Systems Science and Technology Evaluation and Management (TAPSTEM) Committee, and the Joint Engineers.

The Tri-Service S&T Reliance project was implemented in all services by November 25, 1991. (Specific early accomplishments of Reliance are reviewed in Attachment B-1.)

Tri-service coordination plans have been developed for 6.1 research programs in the biological and medical sciences, cognitive and neural sciences, and the environmental sciences. (A list of all tri-service scientific planning groups is provided as Attachment B-2.)

Conclusions

While it is too early to draw conclusions about Tri-Service Reliance, the subcommittee believes that such coordination plans show promise as one mechanism to increase the effectiveness and productivity of research investment dollars across DOD. The *Report of the 1992 Defense Science Board Task Force on Microelectronics Research Facilities*, for example, concludes that Reliance is working well in this area.[7] However, the committee's expert view is that Reliance's achievements to date have been variable. Further development of Reliance should build on its identified successes; and its effectiveness should continue to be assessed and ensured through appropriate cross-service studies.

The Air Force participated actively in project Reliance. It should continue to study and support new initiatives in efficiency, including cooperative research and ways to reduce duplication. The benefits of these efforts, it should be noted, will be seen more over the long than the short term.

At the same time, the Air Force should not give tri-service coordination inordinate weight in its planning of basic research. Satisfying Air Force needs must be a prior goal.

---

[7] *Report of the 1992 Defense Science Board Task Force on Microelectronics Research Facilities*, report to the Office of the Under Secretary for Acquisition, June 1992.

OTHER FEDERAL AGENCIES

In carrying out its comparative analysis, the subcommittee was also briefed by representatives of non-DOD agencies—the Department of Energy (DOE), National Aeronautics and Space Administration (NASA), and National Science Foundation (NSF)—on selected aspects of their basic research management, which are discussed first below.[8] The issues raised—primarily concerning the use of external peer review and maintaining technical managers' skills—led the subcommittee to review some relevant operations of both AFOSR and the Air Force Scientific Advisory Board, which are discussed subsequently. Finally, based on all these observations, the subcommittee offers a number of conclusions toward improving the management of Air Force basic research.

Like AFOSR, DOE and NASA are mission agencies, and their basic research programs are linked to their specific missions. NSF has a much broader, general mandate, namely, to promote and advance scientific and engineering progress in the United States.

U.S. Department of Energy

In DOE, the Director of the Office of Energy Research (OER) is Scientific Advisor to the Secretary and reports directly to the Secretary, one indicator of the prominence that the agency gives to basic research.

The closest analogue to AFOSR within DOE, OER funds basic research at DOE laboratories and universities through competitive processes, including external peer review. Program managers make funding decisions for both on- and off-site projects based on the recommendations of approximately five external reviewers. The reviewers assess proposed projects for relevance to DOE and for scientific merit, and submit their responses by mail. For review of DOE laboratory proposals, external reviewers are selected by the laboratories and program managers together. There is also continual discussion between program managers and the laboratories to sharpen the definition of project areas, both before proposal submission and more generally.

DOE's philosophy is to make long-term commitments to all its investigators (with fewer new starts), especially to those in its laboratories.

---

[8] This comparative study focuses on selected organizations whose missions are in some important way similar to that of AFOSR. However, the Air Force might also benefit from the practice and experience of other agencies, such as the National Institutes of Health (NIH), which supports both intra- and extramural basic research.

Off-site projects must usually be renewed every three years by submitting new proposals. On-site laboratory programs must submit periodic field work proposals (or new proposals if they wish to change research significantly). The lab field work proposals are not subjected to external review. All DOE-funded investigators are also required to submit annual progress reports and professional reprints.

Another DOE technical review process, for ongoing on-site projects, is that used by units within OER's Office of Basic Energy Sciences (BES). In this process, external reviewers make site visits to laboratory programs roughly once every three years (visits to off-site projects are more irregular, carried out only as resources allow). Again, this review is conducted by program managers and reviewers that the program managers and laboratories have jointly identified. Each year, some part of every lab's total program is reviewed in depth in this way. These technical site reviews are advisory only, and their main object is to work in cooperation with the laboratories to improve the quality of their research.

BES research managers report that these external site reviews are an important contributor to the quality of intramural research. In part, the reviews are needed because the laboratories' field work proposals are not externally reviewed. Beyond this, however, this form of review allows obtaining the highest quality scientific advice (because the best scientists anywhere can be asked to participate), as well as some independence in review. Moreover, BES representatives observed, these in-depth, external site reviews are as important in building DOE laboratories' credibility in the scientific community as they are in building quality. BES briefers emphasized that the success of the site reviews appears to depend significantly on the nonadversarial, advisory relationship between the reviewer and the reviewed.

DOE program manager positions in the basic energy sciences are stable, long-term positions, held by GS-15s with Ph.D.s. The briefers identified one weakness of this management pattern: the technical skills of program managers can diminish with time and distance from active research. Program managers' technical skills are maintained in part by working with on-site researchers and by attendance at one or two high-level professional meetings annually. However, the briefers reported, effort is required on the program managers' part to stay abreast of developments in their fields. Some DOE program managers suggest that additional opportunities (e.g., to return periodically to hands-on research) would better help them maintain strong professional skills.

DOE laboratories are maintained as government-owned, contractor-operated (GOCO) facilities, an arrangement that some experts believe offers benefits in managing research.[9] The DOE briefers noted that, under this system, they have greater flexibility in the hiring of personnel. They also observed that DOE contractor-operators conduct additional technical quality reviews of the laboratories they operate.

A number of recent reports on the defense technology base have reviewed the possible advantages—as well as disadvantages—of GOCO research management, along with alternative approaches to achieve its benefits (see, e.g., the earlier cited Defense Science Board, 1987; Defense Science Board, 1992; Office of Technology Assessment, 1989; and Report to the Secretary of Defense, 1991). The possible use of GOCO-type approaches thus appears to remain an interesting option for defense research management.

National Aeronautics and Space Administration

NASA is distinguished by the degree to which its management of research programs, including extramural research programs, is delegated to the NASA centers. NASA's unusual form of management was established through deliberate policy from the agency's beginnings (Office of Technology Assessment, 1989). In this arrangement, NASA operates through a network of field centers (staffed by government employees), which largely define the work to be done, select contractors, and evaluate the work.

The overall NASA research program is formulated through headquarters' issuance of "calls" to the NASA centers and announcements of opportunity (AOs) to industry and universities, seeking proposals for work in specific technology areas. These areas, which are specified at the level of technology thrusts, and sometimes at the level of specific projects, are developed through (1) workshops in which all NASA centers participate; (2) requests for identification of relevant research in a survey of operating (or product) divisions of NASA, such as Space Science, Space Transportation, and Aeronautical Technology; and (3) the discipline-oriented reviews of the Aerospace Research and Technology committees (ARTs), made up of industry and university experts. The projects thus established form the basis of NASA's budget submissions, and also of the agency's advocacy before the Executive Branch and the Congress.

Funds are then targeted to lead NASA centers for the performance or contracting of research in the identified technology areas. Work is monitored by headquarters' discipline leaders, the ARTs groups, and on an annual basis

[9] NASA has also used such an arrangement in its contract with the California Institute of Technology to operate the Jet Propulsion Laboratory.

by the Space and Aeronautical Systems Technology Advisory committees of NASA's Advisory Council.

NASA's Office of Aeronautics and Space Technology, for example, which briefed the subcommittee, uses several forms of external peer review in managing a mixed program of research and technology development. These processes may provide useful models. In initial program planning at the office level, two of the NASA Council advisory committees (the Space Systems and Technology Advisory Committee [SSTAC] and the Aeronautical Systems and Technology Advisory Committee [ASTAC]), whose members are research leaders in industry and universities, meet three times annually to review and provide recommendations on general program area thrusts. Subcommittees look at specific discipline areas (e.g., photonics).

Additionally, the ARTs groups, also consisting of industry and university experts, meet separately during the year to review specific projects. (Like the NASA Council advisory committee members, ARTs members are selected by NASA headquarters, and via peer recommendations.) ARTs groups attempt to examine every NASA office project, both ongoing and proposed. They present their findings annually to SSTAC and ASTAC. These findings are advisory only, but they are considered important and taken seriously.

Office budgetary considerations often circumscribe the way in which the various NASA advisory groups' findings are used. However, all the NASA external review processes, at both program and project levels, are considered valuable by the community. They serve as a respected critique, and provide a basis for advocacy for the NASA office directors and NASA Administrator.

National Science Foundation

The broad mission of the NSF is mirrored in the amount of its research funding—$2.4 billion in 1991, as compared to AFOSR's $170 million—and also in the great attention it has given to developing its peer review procedures. Unlike all other agencies examined in this report (with the exception of ARO), NSF-funded research consists entirely of extramural research.

The high level of competition for NSF funding has been one factor leading to the refinement of the agency's review procedures over the years. Every incoming research proposal is peer-reviewed, in contrast to the practice in other agencies, including AFOSR, where proposals are first screened by program management.

As in the other agencies here reviewed, NSF's peer review of proposals is advisory only, with program officers making final funding recommendations, which are reviewed at the directorate level, or in some cases, at the highest level of NSF technical oversight, the National Science Board. However, at

NSF, as compared to the other agencies, greater weight is given to the views of peer reviewers in reaching funding decisions. In part, this difference in practice owes to NSF's broad (as opposed to user-oriented) mission orientation, the amount of research it funds, and the high level of competition for its research funding. These characteristics have also led to correspondingly high levels of public and federal attention to fairness and oversight.

NSF uses four main criteria in evaluating submitted research proposals: (1) intrinsic merit of the proposed research; (2) the competence of the principal investigator (PI); (3) relevance of research, for applied research; and (4) the effect of the proposed research on the science and engineering infrastructure (human resources, specialized facilities, etc.).

The actual mechanics of the NSF peer review process varies by and within NSF directorate, with review conducted by mail or in panel, or both. Reviewers are experienced PIs, who may be selected by program managers, proposers, or other reviewers. (An attempt is made to balance panelists demographically.) The techniques used by review panels also vary (e.g., they may use different methods of review and ranking).

However, while some NSF reviewing techniques are allowed to vary, all proposal reviews are still required to produce certain results. Proposers must receive the reviews of their proposals, and the anonymity of both the proposer and the reviewers is protected. To help satisfy the last requirement, proposals are technically considered NSF intellectual property. Briefers to the subcommittee noted the advantages of required NSF review results, including the more honest responses reviewers are likely to give when they know they will remain anonymous, and the greater fairness assured in review, with proposers' being provided verbatim copies of their reviews and the chance to improve and resubmit their proposals.

Despite the general sophistication and soundness of NSF review procedures, their development has also led to a cumbersome, inefficient review process for all involved—proposers, NSF research managers and advisors, and the reviewing community. One main conclusion of a recent NSF Merit Review Task Force was that "[NSF review] has become overburdened and creativity and innovation are being threatened."[10] The task force also points to the wide agreement in this view in the scientific and engineering community.

Among other problems in the NSF review process, both the briefers and the task force noted, is the recent great rise in the number of proposals submitted, up 40 percent in the last decade. At the same time, NSF technical staff have remained constant in number, at roughly 1,200 full-time equivalent.

---

[10] Report of the Merit Review Task Force, August 23, 1990, National Science Foundation, Washington, D.C.

Despite various improvements in NSF review efficiency over the years, the growing numbers of submitted proposals have resulted in heavy administrative workloads for NSF research managers. NSF program officers now usually manage 70 to 100 grants (while AFOSR program managers typically manage 10 to 40).

The task force report summarizes the many problems of research management that result from NSF's proposal overload, for program managers, and also for PIs and reviewers:

> ...Carefully reading (and understanding) the proposal, choosing reviewers, documenting specifics, writing recommendations and review summaries, and communicating with PIs, can receive only minimum attention....
>
> Less time is spent on maintaining or enhancing professional expertise in the field(s) supported. Minimal time is available for reading (other than the proposals themselves), for site visits or for attendance at specialized conferences and symposia. This adversely affects the PO's ability to exercise independent judgment, so more reliance must be placed on reviewers. At the same time, it restricts familiarity with the emerging reviewer community, so established scientists and engineers tend to be used more often.
>
> Diminished familiarity with the proposed research (less time available for each proposal in addition to diminished expertise) affects not only the decision process but the ability to communicate effectively with the PI.

NSF does have specific mechanisms to maintain the competence of its technical managers, for example, through the use of visiting scientists and engineers as program managers, and through independent research and development agreements, which permit visiting scientists to remain active in research. Such activities are regarded as a discharge of NSF responsibilities and are clocked as regular work hours.[11]

However, the NSF task force, in light of its findings, makes a number of recommendations to lighten program managers' administrative workload and improve their opportunities to maintain technical skills. The task force recommends that program managers should spend about 20 percent of their

---

[11] NSF Personnel Manual, Chapter 3 ("Employee Development"), March 21, 1989.

time in professional development activities, and permanent staff should have regular opportunities for research leave.

The task force also notes the challenges of NSF's extensive use of visiting scientists ("rotators") as research managers at all levels, including for the management of peer reviews. Between 1983 and 1990, such visiting personnel increased from 22 to 40 percent. While their presence has brought in the perspective of active top scientists and engineers, and valuable institutional changes, it also has its downside, the report points out: "Visitors frequently step into their positions with limited orientation or training.... The management and planning, however, needed to run multimillion dollar programs, divisions or directorates requires a corporate infrastructure that benefits from experience as much as from new personnel and ideas from the outside."

Both briefers to the subcommittee and the task force reported another result of the increased number of proposals submitted to NSF: while average grant size has not changed over the last 10 years, in constant dollars or duration, the costs of research have meanwhile grown significantly, and the average current NSF grant ($62,000) fails to support a research program adequately (the cost of education and training of a single graduate student is now approaching more than $40,000 annually). Moreover, according to the report, the growth in number of PIs and submitted proposals, coupled with federal funding constraints, leads to the favoring of "safe" proposals. An earlier report also identified this problem and pointed out, "to require that the solutions...be obvious before the research is begun discriminates strongly against innovative work."[12]

One NSF program director who briefed the subcommittee had previously served as a program manager at AFOSR. Many of his comments were in keeping with the observations above. He reported that AFOSR does a better job than NSF of post-award management of awards, particularly through site visits, because of the large number of grantees in NSF programs. AFOSR program managers can take more chances than those at NSF when deciding on awards. One notable distinction between NSF and AFOSR is in the amounts of their financial support. In recent years, AFOSR has generally provided funds adequate to do a proposed research project, while NSF often partially funds research, through "grants-in-aid." NSF is currently thinking to increase its grant size, because of the difficulties presented by current award amounts. This briefer's summary of AFOSR's greatest strengths and weaknesses from a comparative point of view are provided in Table B-1.

[12] White House Science Council, Panel on the Health of U.S. Colleges and Universities, "A Renewed Partnership," 1986 (quoted in the NSF Merit Review Task Force Report).

TABLE B-1 One Program Manager's View of the Relative Strengths and Weaknesses of AFOSR in Research Management

Strengths	Weaknesses
Small, efficient, friendly organization	Encumbered by DOD regulations not appropriate for procuring basic research
Highly qualified technical staff	Contracting process too long and burdensome for PI
Respect in scientific community	Declining purchasing power
Reasonable workload; time for professional development	Uncertain budgets, even within fiscal year
Travel funds adequate	Program manager grade/salary levels a source of discontent
Varied work; interactions with academic, industrial, DOD, and other government scientists and agencies	Other restrictions and deficiencies due to U.S. government salaries and regulations
Presubmission contacts and preproposals reduce paperwork	
Funding decisions can be rapid	

Clearly, Air Force attempts to improve its basic research management should benefit from the lessons offered by NSF experience. For example, the observation that heavy workloads and the long-term stability of program manager positions can diminish technical skills is also in keeping with comments made by Army, as well as DOE, briefers. Army experts pointed out that locating the Army Research Office in Research Triangle Park has been critical in maintaining their program managers' professional skills and in increasing the credibility of their research management. ARO research managers benefit through serving as adjunct professors in the Triangle universities.

Maintaining technical competence should be of special concern to the Air Force, with the reorganization of its research command structure. Care should be taken to avoid overburdening Air Force basic research managers with new procedural and process demands. Moreover, in a 1990 annual report to the Air Force Acquisition Executive on Air Force basic research, the Air Force Scientific Advisory Board also recommended that AFOSR staff should participate in a "reverse IPA [Intergovernmental Personnel Act exchange]" to remain current.

Air Force Office of Scientific Research

AFOSR guidance leaves it to the judgment of individual program managers whether they choose to have basic research proposals peer-reviewed (see the AFOSR document on proposal review, in Attachment B-3, and Attachment A-1, item 8). Some AFOSR directorates do use some type of formalized external proposal review, as through contracts with Universal Energy Systems, in the area of life and environmental sciences, and with several boards of the National Research Council, in the areas of chemical and atmospheric sciences and high-energy-density materials, to conduct such advisory reviews. Proposals are first screened by AFOSR for relevance and quality before they are submitted to these formal external reviews. (One AFOSR research manager involved estimated that about 25 percent of proposals received in his area are subjected to formal external review.) In many other AFOSR areas, external review of proposals is conducted only ad hoc.

Those AFOSR personnel consulted who have been involved in formal external proposal review agreed that these evaluations are valuable in managing their own programs of research. They reported that their own external proposal reviews are not expensive (as a percentage of a directorate's budget), and that such reviews help to identify some suboptimal proposals and also some proposals whose value had not been fully recognized by AFOSR.

Also, they report, the use of external peer review helps build the credibility of AFOSR's programs in their own scientific communities.

There has been discussion within AFOSR about regularizing its external proposal review; and members of the subcommittee are highly concerned that AFOSR research should be able to withstand some form of external peer review, to demonstrate its likely scientific and engineering value for the Air Force and the nation.

At the same time, some AFOSR personnel and other observers suggested that regularizing AFOSR external proposal review could raise problems. Some observers pointed out that professional practices vary among scientific fields (especially between scientific and engineering fields), and these "cultural differences" should be in general be respected. Relevance to the Air Force mission, as well as scientific merit, is also important to assess when judging the value of Air Force-funded research, even in the case of basic research. For these reasons, some with experience in the AFOSR environment suggested that it is in fact appropriate to invest the program manager with significant technical decision-making authority. The program manager is in some ways uniquely positioned to be well informed about both the relevance and the scientific merit of Air Force basic research proposals. (The few who argued strongly for this view suggested that good oversight of AFOSR technical managers is therefore a critical means of assuring the quality of AFOSR basic research.)

Others pointed out that conflicts of interest can characterize external as well as internal review, and rigidly formalized external review can lead to overconservatism, as in the case of NSF, which may be especially damaging for basic research. Finally, some observed that regularized, formal external review of research proposals can add paperwork burden, again as in the case of NSF, and related delays and expense, to the detriment of Air Force research management.

It is unclear whether some form of AFOSR external proposal review should be regularized or conducted AFOSR-wide, though this subject may well deserve further examination. A well-designed external review process of some kind can offer strong advantages, including significant added value to the nation and the research mission of the Air Force, as well as increased credibility of Air Force basic research. This credibility will be of growing importance in maintaining the Air Force's basic research, and thus its technological edge, in the face of pressured military budgets. At the same time, inadequately designed external review could add new burdens—notably, delays and additional costs, and the discouragement of innovation—to the conduct of Air Force basic research.

Air Force Scientific Advisory Board

Yet another general mechanism for technical review of Air Force basic research is provided through Air Force Scientific Advisory Board (SAB) review of planned and ongoing 6.1 programs. The Air Force Acquisition Executive (SAF/AQ), not Air Force Materiel Command, assigns SAB the following three responsibilities:

- assessing the general scope and direction of the S&T program;
- advising on technical areas (e.g., with attention to emphases and omissions); and
- recommending guidance for the annual AFAE S&T Executive Guidance Memorandum.[13]

In the area of Air Force basic research, SAB has fulfilled these roles, for both intra- and extramural programs, by reviewing the Research Technology Area Plan (TAP) for basic research, participating in the spring reviews of Air Force Systems Command (to which AFOSR until recently reported), and visiting AFOSR in the fall.

Information provided to the subcommittee indicates that these SAB advisory procedures are considered successful and valuable. However, some SAB representatives and members of the subcommittee are concerned that SAB processes, as they stand, may fail to provide sufficient external, in-depth technical review of Air Force basic research programs. SAB reviews are for the most part general, assessing entire research program areas, rather than specific projects, with only occasional in-depth examination of particular areas (e.g., when the specific technical expertise of an SAB review panelist and the subject of an AFOSR project are a good match).

It may well be that more in-depth, external review of ongoing specific projects is the best means for the Air Force to achieve greater technical perspective and oversight on the value of its basic research. As observed in the discussion on DOE, external project review allows research in progress to be improved, encourages follow-on to specific promising research thrusts, and helps identify research emphases that have become outmoded. (While discussions with DOD representatives did not lead the subcommittee to examine Army or Navy review processes in any depth, it should be noted that Navy briefers did note the importance of the Navy's external review processes for basic research; and various experts have also observed that the Army Research Office's responsibility for extramural projects alone allows ARO to

---

[13] U.S. Air Force Scientific Advisory Board Task on Science and Technology Broad Program Appraisal, September 17, 1990.

serve as an "honest broker" in assessing the Army's intramural research programs.)

Conclusions

Information provided by non-DOD representatives—from DOE, NASA, and NSF—supports the following conclusions concerning the management of Air Force basic research:

1. The Air Force should strongly consider incorporating greater external, in-depth, technical review in managing its research programs, both intra- and extramural. Mechanisms now in place to provide such review appear to be working well, so far as they go. But there are a number of indications that these mechanisms may not be enough. Research today is funded and conducted much more widely throughout the world than it was 20 years ago, and it is increasingly easy for research programs to be isolated from relevant research developments. While the subcommittee appreciates the real uniqueness and value of the technical decision-making role of the AFOSR program manager, it is concerned that current review of AFOSR projects may rest too greatly on the views of too few individuals—however skilled and well informed they may be as individuals. (We also note that, according to the information provided, some elements of the AFOSR program are given very little or no external review of any sort.)
2. Moreover, other federal agencies, including the mission agencies DOE and NASA, are able to achieve greater external, in-depth technical review, and report that such review significantly improves the quality and credibility of their research programs. Both these achievements will be increasingly critical, if the Air Force is to satisfy its research mission in a more highly pressured budgetary environment.
3. In sum, greater external peer review can help greatly in determining that Air Force basic research does not duplicate research done by others, that it stays informed of and capitalizes best on outside research-related developments, and that it is of the highest quality generally. At the same time, Air Force review mechanisms must be designed to ensure that Air Force basic research is best responsive to Air Force needs, including the needs to satisfy mission requirements, contain costs, and avoid new bureaucratic burdens or delays.
4. The subcommittee suggests that further attention be given to achieving greater external technical review of Air Force research, taking into account the views and operations of informed communities, such as AFOSR, Air Force laboratories, AFOSR-funded researchers (representing all research

environments), SAB representatives, and relevant elements of the larger research community. This discussion should include a more detailed evaluation, as appropriate, of particular models used by others, such as DOE, NASA, and NSF. The subject of external technical review is an important and complex one for all concerned, as well as for the Air Force as a whole; it deserves to be addressed in corresponding depth.

5. In view of observations concerning DOE, and especially NSF, program management, AFOSR program managers must be given the workload, span of control, and professional opportunities that will allow them to continually renew their technical skills and standing in their disciplines. These needs are proportionally greater in the degree that technical decision-making authority is invested in AFOSR research managers. In changes following on its recent reorganization, the Air Force should particularly ensure that program managers in basic research are not overburdened with new procedural and process demands.

6. Because of the potential, but uncertain, net advantages of GOCO management, the Air Force should keep in mind the further exploration of GOCO-type arrangements for the management of its basic research.

ATTACHMENT B-1: EARLY ACCOMPLISHMENTS OF THE TRI-SERVICE SCIENCE AND TECHNOLOGY RELIANCE PROJECT

Excerpt from the
"White Paper on Tri-Service Reliance in
Science and Technology"

Joint Directors of the Laboratories
Department of the Army
Department of the Navy
Department of the Air Force

January 1992

- Collocation of all Training Devices and Aircrew Training S&T in Orlando, Florida. This increase in Tri-Service Reliance created a Tri-Service Center of Excellence and eliminates multiple sites performing similar work.

- Collocation of all S&T activity in Survivability and Protective Structures at a single site, the Army Waterways Experiment Station (WES), Vicksburg, Mississippi. This increase in Tri-Service Reliance eliminated redundant capabilities and permitted the reinvestment of resources to strengthen other important S&T areas.

- Collocation of all conventional Guns S&T within the Army at the Armament Research, Development and Engineering Center (ARDEC), Picatinny Arsenal, Dover, New Jersey.

- Collocation of all Fuels and Lubes S&T to Wright Laboratory at Wright Patterson Air Force Base, Ohio. This increase in Tri-Service Reliance involves the Army collocating its Fuels and Lubes program from Belvoir Research, Development and Engineering Center (BRDEC) in order to strengthen the Tri-Service Program while still meeting the enduring mission-essential requirements of the Services.

- Collocation of Army Health Effects research with the Air Force and Navy Toxicology Programs to Armstrong Laboratory at Wright-Patterson Air Force Base, Ohio. This increase in Tri-Service Reliance consolidates major portions of medical S&T through collocation at single sites and creates Tri-Service Centers of Excellence.

- Collocation of in-house S&T work addressing Space-based Wide-Area Surveillance Radar at the Air Force Rome Laboratory, Rome, New York.
- Collocation of in-house S&T work addressing Space-based Infra-red Sensors for Wide-Area Surveillance at the Naval Research Laboratory, Washington, D.C.
- Collocation of all directed Energy Bioeffects S&T of the Army and Navy to Armstrong Laboratory at Brooks Air Force Base, Texas.
- Collocation of all Biodynamics S&T of the Army and Navy to Armstrong Laboratory at Wright-Patterson Air Force Base, Ohio.
- Collocation of all Army Combat Dentistry S&T with the Navy in Great Lakes, Illinois.
- Collocation of Army, Navy, and Air Force 6.1 Foreign Field offices and the development of coordinated science monitoring programs.
- Establishing JDL Centers of Excellence in Artificial Intelligence.
- Conducting inter-Service competition for DARPA Supercomputer hardware.
- Providing an effective Service focal point for developing the DoD Software Technology Plan.
- Providing effective Tri-Service coordination with NASA, the Federal Aviation Authority, and the National Security Agency, and
- Conducting the 1991 OSD Science and Technology Reviews using the Reliance infrastructure.

ATTACHMENT B-2: FISCAL YEAR 1992 TRI-SERVICE SCIENTIFIC PLANNING GROUPS (SPGS)

PHYSICS
Chairman: Dr. B.D. Guenther, ARO
Dr. Sidney L. Ossakow, ONR
Dr. Horst R. Wittmann, AFOSR

CHEMISTRY
Chairman: Dr. Ronald A. DeMarco, ONR
Dr. Donald L. Ball, AFOSR
Dr. Robert G. Ghirardelli, ARO

MATHEMATICAL SCIENCES
Chairman: Dr. Charles J. Holland, AFOSR
Dr. Neil Gerr, ONR
Dr. Jagdish Chandra, ARO

COMPUTER SCIENCE
Chairman: Dr. Jagdish Chandra, ARO
Dr. Charles J. Holland, AFOSR
Dr. A.M. van Tilborg, ONR

ELECTRONICS
Chairman: Dr. G.M. Borsuk, ONR
Dr. J.W. Mink, ARO
Dr. Horst R. Wittmann, AFOSR

MATERIALS SCIENCE
Chairman: Dr. Allan Rosenstein, AFOSR
Dr. Robert Pohanka, ONR
Dr. Andrew Crowson, ARO

Chair rotates in following years:
ARO/ONR/AFOSR

ATMOSPHERIC AND SPACE SCIENCES
Chairman: Dr. Walter A. Flood, ARO
LtCol James G. Stobie, AFOSR
Dr. Robert F. Abbey, Jr., ONR

BIOLOGICAL AND MEDICAL SCIENCES
Chairman: Dr. Robert W. Newburgh, ONR
Dr. William O. Berry, AFOSR
Dr. Shirley R. Tove, ARO

COGNITIVE AND NEURAL SCIENCES
Chairman: Dr. William O. Berry, AFOSR
Dr. W.S. Vaughn, ONR
Dr. Robert S. Campbell, ARO

MECHANICS
Chairman: Dr. Robert E. Singleton, ARO
Dr. Jim C.I. Chang, AFOSR
Dr. Spiro Lekoudis, ONR

OCEAN GEOPHYSICS AND TERRESTRIAL SCIENCES
CoChairman: Dr. Steven Mock, ARO
CoChairman: (TBD), ONR

ENVIRONMENTAL QUALITY SCIENCES
Chairman: Dr. William O. Berry, AFOSR
Dr. Robert W. Newburgh, ONR
Dr. Shirley R. Tove, ARO

ATTACHMENT B-3: PROPOSAL REVIEW IN THE AIR FORCE OFFICE OF SCIENTIFIC RESEARCH

AFOSR's Process of Reviewing Proposals in the Air Force:

The Air Force Office of Scientific Research (AFOSR) invites proposals with a Broad Agency Announcement (BAA) for basic research in support of the Air Force Defense Research Sciences Program. The general areas of interest are:

Aerospace Sciences: structural dynamics, mechanics of materials, structural mechanics, particulate mechanics, external and internal aerodynamics, turbulence structure and control, unsteady and separated flows, air-breathing combustion, rocket and space propulsions, and diagnostics in reacting media.

Chemistry and Materials Science: electrochemistry, inorganic materials, polymer chemistry, molecular dynamics, chemical synthesis and reactivity, theoretical chemistry, metallic structural materials, and ceramic and nonmetallic structural materials.

Physics and Electronics: atomic and molecular physics, optical and plasma physics, electronic and photonic materials and devices, superconductivity, and optical signal processing.

Life and Environmental Sciences: regulation of neuronal responsiveness, neural bases of behavior, computational neuroscience, chronobiology, cognitive processes, sensory and perceptual science, spatial orientation, bioenvironmental science, toxic mechanisms, ionospheric, atmospheric and space environmental sciences, meteorological research, and optical and infrared environment research.

Mathematical and Computer Sciences: dynamics and control, physical mathematics and applied analysis, computational mathematics, optimization and discrete mathematics, signal processing, probability and statistics, software and systems, artificial intelligence, neural computation systems, and electromagnetics.

The primary evaluation factors follow:

1. The scientific and technical merits of the proposed research.

2. The potential contributions of the proposed research to the mission of the Air Force.

3. Availability of funds.

Other evaluation criteria include:

1. The likelihood of the proposed effort to develop new research capabilities and to broaden the research base in support of national defense.

2. The offeror's capabilities, related experience, facilities or techniques or unique combinations of these factors that are integral to achieving the objectives.

3. The qualifications, capabilities, experience, and past research accomplishments of the proposed Principal Investigator, team leader or key personnel who are critical to the DOD mission.

4. Realism and reasonableness of proposed cost.

5. Offeror's record of past research accomplishments.

Policy and Process on Approval Authority of Sponsorship of Research

Sponsorship will only be approved for research proposals aimed at both research excellence and Air Force relevance.

Research proposals which enhance educational opportunities and strengthen the nation's base of mechanically trained personnel (such as through graduate assistantships and support of graduate student research programs) should be evaluated more favorably than research proposals of equal technical merit which do not provide this component.

Upon the completion of a program manager's favorable review, the program manager makes a recommendation (including funding recommendation) to the Director within his/her directorate. The AFOSR Scientific Directors have the authority to approve the use of funds for all US domestic actions up to $1 million in the aggregate. Actions exceeding this limit as well as all sponsorship of foreign research require approval by the Director, AFOSR.

All sponsorship must conform to the budget released by the Plans and Programs Division, XOP, and is subject to the availability of funds. Thus, sponsorship (release of funds), requires approval by the Chief, Resource Management Division.

The Director of Contracts, PK, is authorized to approve all grants and contracts in conformance with applicable AFSC FAR Supplements (currently up to $2 million for grants, $3 million for contracts). This authority may be redelegated in accordance with the AFSC FAR Supplements.

The following chard, Management of Air Force Basic Research, depicts AFOSR's direct process, coordination and policy of how basic research funds are spent, and the funding flow process.

Appendix C:
Quality of AFOSR-Sponsored Research

C. Kumar N. Patel, *Chairman*
Gilbert F. Decker
Daniel P. Schrage
Charles Zraket

One charge to the Committee on Air Force Research Management was to evaluate the quality of Air Force 6.1 (basic research) programs, that is, programs sponsored by the Air Force Office of Scientific Research (AFOSR). The report of this subcommittee specifically addresses this charge.

The subcommittee considered in particular the relative quality of AFOSR intra- and extramural research. It also touched on another study charge in the course of its work: assessing the means and extent of technology transition by performers of Air Force 6.1 research. The practical value of research—as seen in technology transition—is one of the most important ultimate measures of research quality.

Clearly, high-quality basic research has a significant impact on Air Force technology and mission accomplishment. At the same time, ensuring high-quality research requires the use of appropriate quality metrics, which are difficult to specify for basic research. Good basic research is often driven more by scientific than practical, goal-oriented motivations; and its full impact may not be evident for many years.

As a first step, the subcommittee therefore identified a variety of measures that can be useful, if imperfect, indicators of basic research quality (Attachment C-1). They concern the quality of research personnel, the quality of research results, technology transition, contribution to the knowledge infrastructure, and assurance of long-term scientific manpower needs. The identified measures include those used by universities, private research laboratories, and peer review and accrediting committees in their assessments of basic research quality. These measures also include those that the subcommittee identified with AFOSR's particular needs in mind.

After outlining AFOSR's current review processes below, the subcommittee evaluates these processes in light of measurement criteria selected from the subcommittee's identified list. Caution is urged in the use of the suggested criteria, because none of them alone provides a full picture. At the same time, each has some validity, and a variety of these criteria taken together can offer a good starting point for better measurement, and thus management, of Air Force basic research.

CURRENT AFOSR REVIEW PROCESSES

AFOSR fully recognizes that developing and implementing an optimal review process for Air Force basic research is a multidimensional, complex issue. Factors contributing to this complexity include the following:

- the wide range of disciplines in which the Air Force sponsors basic research;
- the large number of Air Force 6.1 research projects, or work units, underway at any given time (roughly 1,500 work units[1]); and
- the large number of institutions, geographically widely dispersed, at which Air Force basic research is conducted.

AFOSR does carry out its own audit of the quality and effectiveness of the research it supports, by means of review processes that have been refined and improved over the last three years:

- New review responsibilities have been defined for AFOSR's program managers and the scientific directors to whom they report. Quality standards and the review responsibilities of program managers and scientific directors have been clarified.
- "Relevancy" reviews are conducted at each of the Air Force laboratories annually during the fall; in these reviews, the laboratories evaluate the AFOSR basic research programs in general, with emphasis on relevance to Air Force needs.
- Quality reviews are also held at these fall meetings, with quality review forms being completed by invited members of the Air Force Scientific Advisory Board and the AFOSR scientific directors.
- The relevancy review inputs and the quality review inputs are compiled by AFOSR into two overall numerical ratings for each project, one for excellence (or quality), the second for relevance.
- In a spring review also held by AFOSR, general progress of ongoing programs is assessed, new initiatives are considered (this is advertised as the point where innovative ideas can be addressed), and future plans for ongoing programs are reviewed.

To better assess the effectiveness of AFOSR's review processes in action, several members of the study committee attended three of the four fall

---

[1] Headquarters, Air Force Materiel Command, *FY 93 Research Technology Area Plan*, DCS/Science and Technology, Wright Patterson Air Force Base, Ohio.

reviews held at the Air Force laboratories. The following observations were made:

- Because of the many work units covered, only research abstracts were presented at the meeting; there was effectively no in-depth review of the research.
- No researchers from AFOSR's extramural programs were present at the reviews.
- Attendance by external "peer" reviewers, including members of the Air Force Scientific Advisory Board, was limited.

Findings

Based on the information it was provided through the briefings and site visits, the subcommittee reached the following findings:

1. Significant improvements have been made in the last few years in AFOSR's review processes, especially in evaluating the relevancy of basic research to Air Force needs.
2. The fall reviews are fundamentally internal reviews, and, while they provide useful indicators of relevancy, they provide questionable indicators of quality, and little or no in-depth review of technical subject matter.
3. The review of research quality is very highly decentralized, depending almost exclusively on the capabilities and initiative of the responsible program manager.
4. The failure to apply any quantitative, and also some qualitative, measures of research quality (as described below) makes the evaluation of AFOSR-sponsored research very difficult.
5. Little dependence is placed, either formally or informally, on the views of outside review groups.
6. Some information is available on the quality of the basic research program, as measured by the current review process, but it has not been integrated into overall statistics nor independently validated.
7. There is very little overall strategic planning for AFOSR's basic research program. While many program managers appear to do a credible job of managing within their own domains, overall goal-setting in light of long-term Air Force needs appears not to receive adequate attention.

CRITERIA TO EVALUATE RESEARCH QUALITY

Having examined current AFOSR review processes, the subcommittee used some of the measurement criteria it had identified (Attachment C-1) to benchmark these processes. The section below discusses these selected criteria and presents related observations and findings about AFOSR review.

Personnel

In mature fields of science, interesting problems become increasingly complex, often requiring team efforts to arrive at solutions. Even so, first-rate research teams are generally composed of first-rate individual researchers. A number of objective measures can be used to evaluate the performance of both the individual researcher and the research team.

Objective Measures

Objective quality metrics for individual research personnel include the following:

- fellowships in professional societies;
- memberships in national academies; and
- other forms of professional recognition, such as society prizes and awards.

These criteria are characteristic of the highest caliber researchers, reflecting peer evaluation of the sum total of an individual's contributions to date. Researchers in the best university research groups tend to rank very high according to these criteria.

The following group measures can also be useful in assessing the quality of research personnel:

- breakdown by advanced degrees and scientific and engineering disciplines; and
- average professional age (and age distribution by fields and degrees).

While past performance may not be a perfect indicator of future accomplishments, the above measures do provide some collective insight into the quality of people doing research.

The subcommittee was unable to obtain information regarding any of the above measures for AFOSR-supported personnel. It appears that such data are not routinely compiled for any AFOSR-supported research personnel, whether university faculty, industry researchers, or Air Force laboratory personnel. This is unfortunate. The absence of such data for Air Force laboratory personnel in particular makes it especially difficult to draw any significant conclusions about the overall quality of researchers AFOSR supports.

In this context, it is important to note AFOSR's use of the Star Team Award, which recognizes excellence in basic research in the Air Force laboratories. These awards are based in part on some of the quality criteria identified here and below. They appear to be a well-designed, valuable tool for rewarding and promoting excellence in research. At the same time, they are not designed to serve as general measures of the quality of all Air Force basic researchers or of all Air Force basic research.

Subjective Observations

AFOSR did provide the information it had readily available on the research personnel it supports. This information consisted of a nearly complete list of current AFOSR research projects and grants, by subject title, name of the principal investigator (PI), and the PI's institution. Based on these data, the subcommittee was able to draw some general qualitative inferences about the quality of research personnel to whom AFOSR awards grants and projects.

The grants are distributed over a very large number of academic institutions. By itself, this is not an indicator of personnel quality, but an indicator of program diversity. However, the number of grants to better known, highly rated research institutions appears proportionally greater than the number of grants to less well known institutions. PIs at these highly rated institutions are more likely to be top-quality researchers, given their institutions' high standards, and thus high standards are likely being used by AFOSR program managers in their grant selection. A review of the names of university researchers supported by AFOSR, in fields familiar to the subcommittee, indicates that well-known individuals are often carrying out the research (though in some cases the researchers are past their most productive period of research). It is more difficult, of course, to assess how many of the researchers unfamiliar to the subcommittee are those who are up-and-coming in their fields but not yet well known.

Discussions with the Director of AFOSR and several research program managers suggest that, in AFOSR's consideration of grant proposals and review of research content and progress, it is generally left to the individual program manager to assess the quality of research personnel. Some program managers reportedly try to apply more rigorous methods than others in assessing researcher quality. Again, no systematic database is maintained on the objective quality metrics for research personnel that were identified above.

Finding

The lack of an organized database on objective quality metrics is a serious deficiency in attempting to evaluate the overall quality of researchers to whom AFOSR awards grants and projects. Without such a database, the assurance of quality standards is left to the highly subjective judgment of individual program managers. The sound evaluation of research personnel requires a more objective basis.

Research Results

One critical outcome of research is new knowledge, which provides the foundation for new technologies. An important mechanism for disseminating and validating new knowledge is publication in refereed journals. The full impact of a publication—its contribution to the knowledge base—is difficult to assess without an in-depth understanding of the relevant field. However, a helpful and widely used, if imperfect, measure of a publication's impact is the frequency with which it is cited by peers.

Unfortunately, such publication and citation data are not kept by AFOSR on the work it supports, even as a rolling data bank that may look back three to five years. The quality of AFOSR research results is also assessed largely through the judgments of individual AFOSR program managers. Again, for the well-known researchers supported by AFOSR, the subcommittee can be reasonably sure that their publications have value, but only in these cases and in familiar fields. Statistical data on publications and citations for AFOSR-sponsored work would provide better quality measures of research results. These data would make possible, for example, a more rationally based assessment of the relative contributions of intra- and extramurally conducted research.

Another useful measure of the value of research results is patent activity. The number of patents assigned to AFOSR-supported work would be one indication of the return on Air Force basic research investments. When good products, processes, algorithms, or other ideas emerge from AFOSR-sponsored research, their value to the nation can also be protected by obtaining patent coverage. While AFOSR does not appear to be neglecting patent activity, it collects no data to help ensure that the nation's economic interests are adequately protected.

Finding

The lack of an organized database on publications in refereed journals, citations, and patent activity resulting from AFOSR-sponsored research is a serious shortcoming for Air Force basic research management. The absence of such data makes it hard to assess the impacts of specific grants or to compare the impacts of intra- and extramural research. Such data could also be used as supplementary information (along with the earlier-described quality measures for research personnel), to improve the pool of AFOSR researchers.

Technology Transition

Another dimension of research results is the effectiveness of technology transition from basic research to applied science and engineering. In the current Air Force structure, the mission of technology transition is shared by AFOSR and the Air Force laboratories.

Leadership is clearly aware of the importance of technology transition, and many Air Force activities are designed to effect or enhance the transition of basic research results. These activities include the intramural basic research program itself, the spring and fall reviews, the maintenance of overseas offices in Europe and Japan, and the recent establishment of AFOSR's S&T Coordinator Program. In this program, some program managers are selected to serve as liaisons between discipline-oriented basic research and the multidisciplinary, technology-oriented work of the laboratories. The designated S&T coordinators serve as resources, advisors, and organizers of activities (e.g., meetings and workshops) for about 20 major technology areas.

All these efforts are certainly merited, and there is much anecdotal information to suggest that technology transition does occur successfully within the Air Force. At the same time, there is once again no organized, accessible, central information base on technology transition from Air Force research projects to Air Force (or other DOD) development projects. The subcommittee therefore could not make any quantitative assessment of the effectiveness of technology transition for AFOSR-sponsored research.

Some general information was provided by the AFOSR scientific directors who briefed the committee. They were certainly aware of their responsibilities to help in transitioning their research results into development projects. (However, the subcommittee did not perceive this cognizance as uniform throughout AFOSR.)

Additionally, a special briefing to the committee covered "Basic Research Initiatives to Battlefield Capabilities." The briefing provided an overview of a dozen technology areas in which the research results from AFOSR had eventually been transferred through development into fielded capabilities. Assuming the accuracy of this historical analysis, the subcommittee concluded that the traditional means of technology transition used by the Air Force, namely, highly decentralized dependence on the laboratories and AFOSR research managers, sometimes pays off. To what degree it should pay off and to what degree it is paying off could not be assessed because of the lack of data.

Finding

The lack of a centrally maintained database on the transition of AFOSR research results into applied science and engineering impedes Air Force assessment of the effectiveness of this process.

Contribution to Knowledge Infrastructure

Basic research contributes to the knowledge infrastructure for Air Force technologies through both successful and unsuccessful projects. Analyses of both kinds of projects can contribute significantly to the value derived from research. A organized knowledge base on these projects could enrich all of the following activities:

- evaluation and selection of research proposals;
- advanced stages of research and development where the engineering of systems begins; and
- justification of the basic research program to those who make decisions relating to its resources and funding.

Currently, there is no systematic capture, storage, and distribution of the results of Air Force basic research projects. Much documentation does exist in the form of miscellaneous documents—published papers and unpublished progress and project reports.

In selecting research projects currently, AFOSR relies heavily on the judgment of individual program managers. The operating philosophy is to select top-quality people for these positions, assuming that the quality of project selection and management will follow. While the subcommittee generally supports this philosophy, it still believes that the lack of an organized knowledge base on the results of prior AFOSR research projects hampers the ability of program managers to carry out the selection of top-quality programs. The ability of a research manager to compare proposals for research projects to the well-documented results and knowledge gained from prior research is invaluable in selecting new projects.

In advanced development projects, Air Force laboratories undoubtedly try to capitalize on knowledge gained from prior Air Force research, even when projects are conceived in response to Air Force requirements ("customer pull"). It seems, however, that this transfer of knowledge is left largely to serendipity, and that much could therefore be gained from an organized knowledge base.

Moreover, notwithstanding the frustration of scientific managers and researchers with the bureaucracy of accountability by seemingly unknowledgeable people, significant justification will continue to be demanded for defense research that uses public funds. The lack of a systematic knowledge base derived from both anecdotal and quantitative results is a serious shortcoming from this perspective as well.

Finally, such a knowledge base would be an invaluable management tool for the entire basic research management chain of the Air Force.

Finding

The lack of an organized knowledge base (library function) of "what was learned" from Air Force basic research projects is a serious shortcoming in the management and use of project results.

Meeting Long-Term Scientific Work Force Needs

The quality of Air Force basic research depends of necessity on the quality of its long-term scientific and engineering work force. This work force includes not only researchers in the Air Force laboratories and in universities, but also the much larger contingent of those employed by Air Force contractors and related commercial establishments that carry out research, development, testing, and evaluation (RDT&E). To guarantee the reliable delivery of technology over time, AFOSR has been active in ensuring that related long-term scientific work force needs are met.

In this area, the subcommittee identified five indicators of quality activity:

- funding of university scientific manpower to do research;
- number of Ph.D.s, research fellows, and graduate students supported by AFOSR;
- in-house programs (for postdoctorate and graduate student researchers, faculty on research sabbaticals, etc.);
- short-term assignments of university faculty and graduate students in Air Force laboratories and AFOSR; and
- women and minorities supported at universities through grants to PIs, research fellowships, and graduate assistantships, and employed as professional staff in the Air Force laboratories. Women and minorities represent an ever-increasing proportion of the U.S. work force. Failure to capitalize on this pool of talent would constitute a lost opportunity to improve work force quality.

Reasonably comprehensive data were provided to the committee on these criteria.

Funding of University Research Personnel

Several types of Air Force basic research funding go to support university research personnel. The Defense Research Sciences (DRS) program, which accounts for most Air Force basic research, is funded at about $210 million for fiscal year 1992 and is expected to remain roughly constant over the next few years.[2] About 60 percent of DRS funding goes to researchers at colleges and universities, along with about $20 million in additional funds (in 1992) through the University Research Initiative (URI) program. Thus, roughly $146 million of Air Force basic research funding goes to support research and researchers at universities.

Finding

To achieve its mission, the Air Force must sustain appropriate leads in basic research now and in the future. A sufficient scientific work force will be needed to sustain these leads. Current levels of Air Force support for university research personnel appear appropriate, based on the subcommittee's informal judgment. Nevertheless, especially in the face of

[2] Sources of figures this paragraph are Headquarters, Air Force Materiel Command; and personal communication, Sally Brown, Executive Assistant, Director's Office, Air Force Office of Scientific Research, November 10, 1992.

expected budgetary constraints, a good quantitative estimate is needed of future Air Force scientific and engineering work force needs. The subcommittee notes that significant time is required to bring research personnel through the educational pipeline, and thus, to provide adequate support of the long-term Air Force scientific work force, it would be better for the Air Force to make its estimates conservative.

AFOSR Science and Engineering Education Programs

Additionally, AFOSR devotes some DRS and URI funds (totaling over $15 million in 1992) to support special programs of postdoctoral and faculty exchange, and science and engineering education:

AFOSR maintains three dedicated programs of postdoctoral and faculty exchange:

- USAF National Research Council Resident Research Associateship Program;
- Summer Faculty Research Program; and
- University Resident Research Program.

It also maintains four dedicated science and engineering education programs:

- Graduate Student Research Program;
- High School Apprenticeship Program;
- Laboratory Graduate Fellowship Program; and
- National Defense Science and Engineering Graduate Fellowship Program.

In 1993, about 225 faculty and postdoctoral students will be supported by the postdoctoral and faculty exchange programs, at least 150 in the summer program and nearly 75 in the other two exchange programs.[3] All but the first are in-house programs. The science and engineering education programs support about 125 full-time graduate student fellows, 100 graduate student researchers in the in-house Graduate Student Research Program (an adjunct to the Summer Faculty Research Program), and about 125 students in the high school apprenticeship program.

[3] Headquarters, Air Force Materiel Command, *FY93 Research Technology Area Plan*, op. cit.

Special emphasis is placed in all these programs on increasing the number of women and minorities in science and engineering. In the National Defense Science and Engineering Graduate Fellowship program, ten percent of the awards are set aside explicitly for underrepresented minorities.

AFOSR also encourages the development of the future science and engineering work force by means of its other basic research programs. Project proposal review criteria specify that more favorable consideration be given to proposed projects that would strengthen the nation's base of technically trained personnel (e.g., through graduate assistantships).

All forms of AFOSR support for university research personnel provide advantages beyond the maintenance and development of the science and engineering work force. The funding of university researchers greatly leverages Air Force resources, inasmuch as university research is funded by a variety of sources. Additionally, exchange and support help facilitate the transfer of outside advances to intramural programs, and build the university research community's interest in research areas of special advantage to the Air Force.

Finding

The AFOSR science and engineering education programs for faculty and postdoctoral and graduate students appear well designed to meet their objectives. They support a sizeable number of research personnel, and their emphasis on in-house programs and women and minorities appears reasonable. Considering the future needs of the Air Force and the nation for a healthy science and engineering work force, and also the leveraging and technology transfer opportunities available through funding university researchers, Air Force programs in this area are highly valuable. Their funding levels should be assessed in this light, and taking into account the results of the earlier recommended assessment of future work force needs.

CONCLUSIONS

The general quality of research activities supported by AFOSR is probably acceptable and even very good. But there are significant deficiencies in Air Force procedures for measuring and assuring research quality. The subcommittee is convinced that the value of Air Force intra- and extramural basic research can be substantially enhanced by addressing these deficiencies.

1. Beyond its current review processes, AFOSR should implement the following review procedures:

a. AFOSR should randomly select projects representing perhaps 10 percent of the annual Air Force basic research outlay each year and subject them to detailed external peer review. The results of these reviews should then be compared with evaluation ratings obtained through internal review to reinforce the validity of internal review processes. (The Department of Energy, for example, carries out external reviews of each of its projects once every three years; see Appendix B.)

b. AFOSR should conduct internal, in-depth reviews of one-third of its research projects each year, so that every research project with a life of three years or more is subjected to rigorous benchmarking. This should be an ongoing process.

2. AFOSR should institute a process to monitor the quality of the scientists and engineers it supports. The objective and subjective measures described under the discussion of "Personnel" above should be applied and updated annually. The following specific steps are suggested:

a. An organized database on objective measures of the quality of research personnel should be created and maintained, to describe the overall quality of the pool of researchers supported by AFOSR grants and awards.

b. This database should also be used to improve the mix of scientists supported by AFOSR, without being unduly concerned about the relative fractions of AFOSR funds expended intra- and extramurally. Since the objective is to provide the best research for the Air Force's future technological needs, funding should follow the best people.

3. AFOSR should also institute a process to create and maintain databases on the following:

a. Publications in refereed journals, citations, and patent activity resulting from AFOSR-sponsored research. Among their other values, these quality parameters can be used to help determine the relative value and cost-effectiveness of intra- and extramural research.

b. Scientific impact and transition of research results to applied science, engineering, and Air Force materiel acquisitions. Such a database would be of great help to AFOSR research managers in measuring the effectiveness of their programs and improving the mix of their portfolios. This database would also help the AFOSR Director in prioritizing areas of the AFOSR research portfolio.

c. "What was learned" from Air Force basic research projects. This information base could help AFOSR research managers more effectively manage their research projects and better use their research results.

4. AFOSR should ensure that a good quantitative assessment is made of the future Air Force scientific and engineering work force needs, especially for research and development. This assessment should result in a strategic

plan for the support and development of faculty and postdoctorate and graduate students. Until this new plan is in use, AFOSR should continue to maintain its current funding levels for the support of university research personnel and science and engineering education programs. (Such planning must be based on incomplete facts, but the process of planning forces a valuable discipline, yielding important insights and plans will be amended both with this experience and as more accurate information becomes available.)

5. The quality metrics identified by the subcommittee should be used as the basis of an AFOSR annual report, to describe the quality and effectiveness of its program. AFOSR should apply the quality metrics as an ongoing audit, for better assessment of the value of its research, use of its research funds, and justification of its program. The quality metrics should be refined through their ongoing use. (See also the subcommittee's outline on measurement criteria, Attachment C-1. Other promising quality criteria, such as the Malcolm Baldridge National Quality Award Criteria, should also be considered in AFOSR's development of quality metrics.)

ATTACHMENT C-1: CRITERIA TO ASSESS THE QUALITY AND RELEVANCE OF AFOSR RESEARCH

The subcommittee that examined the quality of Air Force basic research began by identifying some of the criteria through which research quality could be assessed. In developing its criteria, the subcommittee considered relevant measurement dimensions and corresponding metrics; processes, means, and tools; and implementors and executors. All these measurement features must ultimately be well specified for a good assessment of Air Force basic research.

A selected set of the criteria presented below were used by the subcommittee in its analysis. AFOSR is encouraged to explore these and other quality criteria in developing good measures for its research activities.

Research Quality

Dimensions

1. Personnel
2. Research results
3. Contribution to the knowledge infrastructure
4. Assurance of long-term scientific work force needs
5. Appropriate research management of ongoing activities

Metrics

1. Personnel
   a. Fellowship in professional societies
   b. Membership in national academies
   c. Other professional recognition (prizes and awards)
   d. Breakdown by advanced degrees and scientific and engineering disciplines
   e. Average professional age
2. Research results
   a. Publications in refereed journals
   b. Citation index
   c. Patent activity
3. Contribution to the knowledge infrastructure
   a. Project documentation (both of projects that have succeeded and of those that have failed)

b. Project post mortems and their documentation

4. Assurance of long-term scientific manpower needs

a. Funding of university research work force

b. Number of faculty, and postgraduate and graduate students supported by AFOSR (through research fellowships, other special science and engineering education programs)

c. In-house programs (support of postdoctorate and graduate students, faculty on research sabbaticals, etc.)

d. Short-term assignments of university faculty and graduate students in Air Force laboratories and AFOSR

e. Women and minorities supported at universities through grants to PIs, research fellowships, and graduate assistantships, and employed as professional staff in the Air Force laboratories

5. Appropriate research management of ongoing activities

a. Effectiveness of interim measurements of project progress

Processes, Means, and Tools

1. Leveraging the research activities and results of others, including Air Force laboratories, universities, other service organizations (especially the Army Research Organization and Office of Naval Research), other federal agencies (e.g., the National Aeronautics and Space Administration, Federal Aviation Administration, and Department of Commerce), and industry

a. Does the planning and review of AFOSR research content reflect appropriate cooperative efforts (forums) at the scientific level?

b. Does Air Force basic research adequately exploit joint projects—at the right level and through appropriate means?

c. Through what types of efforts does AFOSR interact with industry, particularly in Independent Research and Development (IR&D) projects? Are there barriers to these kinds of interaction?

2. In-house research

a. Annual reviews (Is balanced attention given to programmatics and scientific content?)

b. External review teams and visiting committees (What processes, criteria, and standards are used? Who participates? Are there standing visiting committees?)

c. Ongoing internal review/milestones

3. Extramural (especially university-based) research

a. Frequency and quality of reports

b. Frequency of site visits by AFOSR program managers and level of interaction during site visits

c. Review and decision process for proposals (both new and renewal)
d. Use of forums involving principal investigators and peers

Research Relevance

With regard to measuring research relevance, attention should be given again to all features of the measurement system: the dimensions of measurement and specific metrics; processes, means, and tools; and implementors and executors.

Dimensions and Metrics

1. Use of research results in Air Force or other DOD systems
   a. Contributions to 6.2 and 6.3 activities
   b. Contributions to troubleshooting of current operational problems
   c. Contributions to meeting requirements or statements of need
2. Impact on other national needs
   a. Contributions to U.S. economic health (dual-use technologies)

Processes, Means, and Tools

Use of appropriate evaluators of AFOSR research relevance (e.g., representatives of Air Force laboratories; Air Force end users/operators; industry/contractors; other DOD entities, such as the Army Research Office and Office of Naval Research; or other government entities, such as the Department of Commerce or White House Office of Science and Technology Policy).

Appendix D: Meetings of the Committee on Air Force Research Management

March 8, 1991	Chairman/Dr. Schell	Washington, DC
May 1, 1991	Planning Session (Sponsor)	Washington, DC
June 10, 1991	Briefings	AFOSR
July 16–17, 1991	Briefings (ARO, ONR, OSD, DARPA, AF labs)	Washington, DC
August 15, 1991	Subcommittee Lehmann, Miley	Wright-Patterson AFB (Wright Lab)
August 20–22, 1991	Subcommittee Lehmann, Miley	Brooks AFB (Armstrong Lab)
September 18–19, 1991	Briefings (AFSAB, NSF) Subcommittee Meetings	Woods Hole, MA
September 27, 1991	Subcommittee Rock, Kerrebrock	Hanscom AFB
November 6, 1991	Subcommittee Parks, Patel, Green, Decker, Zraket, Weiss	AFOSR
November 12–14, 1991	Subcommittee Zraket	Hanscom AFB (Rome Lab)
December 9, 1991	Subcommittee Parks, Baciocco, Ippen	Washington, DC (DOE, NASA)

December 11, 1991	Subcommittee Lehmann	Brooks AFB (Armstrong Lab)
December 12–13, 1991	Subcommittee Weiss	Kirtland AFB (Phillips Lab)
December 17–19, 1991	Subcommittee Miley	Wright-Patterson AFB (Wright Lab)
January 29–30, 1992	Draft Report	Washington, DC
February 6, 1992	Subcommittee Miley	Wright-Patterson AFB (Wright Lab)
February 11, 1992	Subcommittee Lehmann, Miley Kerrebrock, Rock	Conference Call
August 18–19, 1992	Draft Final Report	Woods Hole, MA